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THE WOOTTEN LOCOMOTIVE.

[*Report of the Committee on Science and the Arts.*]

[No. 1,565.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 1, 1890.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination and report,

THE WOOTTEN LOCOMOTIVE,

respectfully report that they have examined the working and illustrative drawings submitted to them, also the copies of the specifications of United States Letters-patent Nos. 192,725, 234,581, 291,126, 352,215, 354,370, 368,681, granted therefor, and the locomotive in use and at work and also those in course of construction, and find as follows:

The distinguishing features of these engines as compared with others is a much greater breadth of furnace and larger

area of grate with a less depth of fuel thereon, a change in the location of the cab from the rear of the engine and at the sides of the fire box to a position above the furnace, in some instances, and in others on each side of the waist of the boiler immediately in front of the fire box, the steam dome being located in the cab.

The construction of frames, driving wheels, cylinders and steam chests are not strikingly different from other well-known and usual types of engines.

This engine has been gradually developed into its present form and to give a fair and clear conception of its merits, a concise history of its development and causes leading to its invention appears to your committee as not inappropriate in this place.

At the outset, a demand, constantly increasing, for cheaper freights and diminished expense for motive-power in drawing trains, compelled the use of trains of greater capacity, so as to reduce the cost of wages relatively to the tonnage hauled. This necessitated more powerful engines, and whilst it was not difficult to increase the cylinder capacity or piston displacement of the engines, the limit of the boiler to supply adequate steam to such engines was soon reached.

The gauge of the railroad appeared to limit the width of the boilers admissible, the frames could not be spread any further apart, and under the practise of placing the furnace of the boiler between the frames, the only increase of grate surface practicable was in the direction of length. This rendered firing more difficult, and a deep bed of fuel was required to maintain steam pressure, the draught of air to maintain combustion demanded greater pressure on the exhaust, which could only be enforced by contracting the nozzle of the exhaust pipe and imposing a pressure upon the steam pistons during the return strokes. This, in view of the large piston surface recently coming into vogue, especially in compound locomotives, means a serious waste of force.

In addition to the above incentives to improvement, immense quantities of perfectly good coal, in dust and small grains, was steadily accumulating around every mine, and

whilst its value, when burned in a well-adapted furnace in a stationary engine, was a matter of daily demonstration, no long furnace or deep bed of such fuel was able to burn it upon a railway locomotive, and, moreover, a deep fire of such fuel would not burn, because the draft could not be forced through its entire surface, without much of the fuel being carried beyond reach with the then generally adopted furnaces.

The solution of this difficulty was found in an increased breadth of furnace—grate and fire box to accommodate it. Space to contain such boilers without interfering with the driving wheels was procured by placing the boiler above the driving wheels and frames, which were protected from ashes by a hopper-shaped ash pit.

The boiler then had broad expanses of nearly flat metallic external, as well as internal surfaces, having cross seams exposed to high internal pressure and required to be securely stayed or braced. The form of the plates presented oblique opposing surfaces, and stay bolts diagonal to such surfaces were applied to hold them together.

The oblique strain upon such stays, and the oblique intersections of the stays and plates, were subjected to shearing or diagonal strains, and the failure of such stays by breaking close to the plates, became a conspicuous objection to such structures.

An inspection of the cross and lengthwise sectional views of these earlier forms of the invention will serve to show the cause of this.

The remedy was found in changing the form of the furnace and the portion of the external shell of the boiler enclosing it so as to bring nearly parallel surfaces, formed of large plates without cross seams, opposed to each other. After this, the stays uniting them were subjected only to direct tensile strains and withstood them.

The fuel in such broad expanses of surface developed volumes of combustible gas, which burned with best effect when in large body or volume, but only imperfectly when subdivided by entering the flue tubes, so a combustion chamber was added.

The volume of draught usual with large fuel, when applied to fine or pulverulent fuel on a small grate surface, lifts and carries much of it mechanically from the furnace, but in the broad expanses of grate furnished in this boiler, the same volume passes through a lower velocity and with less pressure, so that instead of sweeping particles of fuel through the tubes with the products of combustion, the fine ash only appears to pass and deposit in a flocculent state in the smoke box and chimney.

The changes in form of the boiler, which we have thus far noted, are with reference to the combustion of fuel and generation of heat and durability of the boiler.

From experience it appeared desirable to place as much of the weight of the boiler as practicable lower down.

This was effected by the partition or bridge, excluding the fuel from the combustion chamber, in the shape of a dam, with the flue tubes and waist lower down in relation to the grate surface.

The combined effect of these improvements can best be understood by the report of the engine as worked upon the roads.

A sufficient proportion of the weight of the engine is placed upon the front truck wheels, serving to guide it securely upon the rails, whilst as large a proportion as is practicable is utilized in compelling adhesion between the driving wheels and the rails for purposes of propulsion.

A capacity for burning fuel, impracticable in furnaces of small grate area and large depth of fire bed, and an economy in quantity as well as quality of fuel required, ensued.

The several stages of improvement are set forth in the letters-patent, the drawings of which with a brief notice of their features are here stated.

The development of this invention, as it appears in the several letters-patent, is shown in the drawings reproduced from the patents and hereinafter briefly stated in chronological order.

In letters-patent 192,725, of July 3, 1877, the hopper-shaped ash pit and fire box extending sidewise over the rear driving wheels of one engine with six drivers and four

truck wheels is shown, the combustion chamber being over the middle driving-wheel axle and included in a tapering part of the boiler uniting the fire box portion with the cylindrical waist. The claim of this patent is for a fire box wider than the distance between the wheels, and for the combustion chamber in combination with a bridge wall.

In letters-patent No. 254,581, of March 7, 1882, the ash pit is in the form of two rectangular funnels or hoppers, the grate is inclined from rear downwardly to the front, a flat crown sheet is used, stayed by parallel vertical stays to the outer curved shell, and the proportion of the combustion chamber in length to the furnace chamber is reduced.

In letters-patent 291,120, dated January 1, 1884, the forward part of the grate immediately in the rear of the bridge wall and across the entire width of the fire box is covered with fire brick to receive small particles of fuel which the draft through the grate would otherwise sweep over the bridge wall.

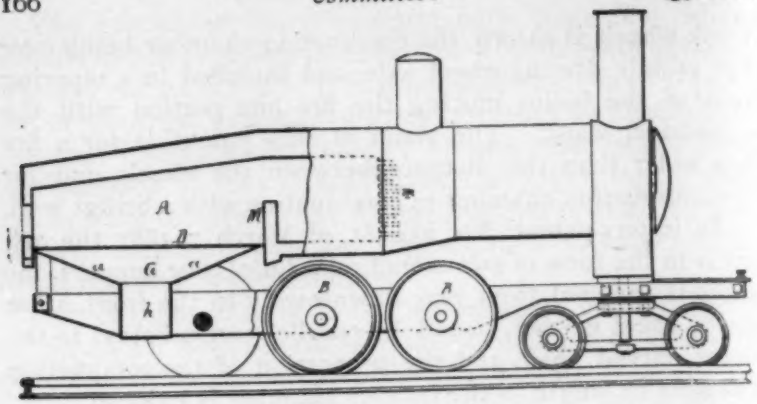
Patent No. 352,215, of November 9, 1886, shows an improved form of bridge wall which practically separates a combustion chamber within the fire box from the fuel supporting space on the grate.

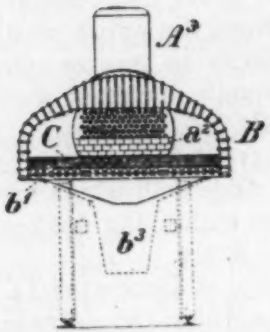
Patent No. 354,370, of December 14, 1886, is for a construction of boiler in which the rearward flue sheet of the furnace is without perforations, and acts as a bridge wall dispensing with the separate bridge walls in the preceding forms of this boiler.

Patent No. 361,661, of April 19, 1887, to J. F. Wootten and J. Snowden Bell, is for a form of this boiler in which a central partition or water wall is introduced in the furnace, making in effect two furnaces, with a bridge wall between the furnaces and the combustion chamber and flue.

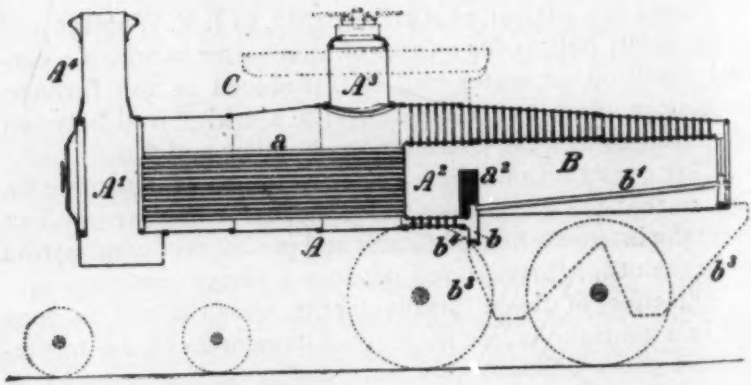
This construction offers the advantages of alternate firing, so that the gases from the fresh fuel in one furnace, can meet the intensely heated flames and products of combustion from the other furnace, and produce a better combustion.

The effect of these improvements, which it will be seen are in a continuous line of gradual development, are to produce a most efficient and serviceable boiler, capable of

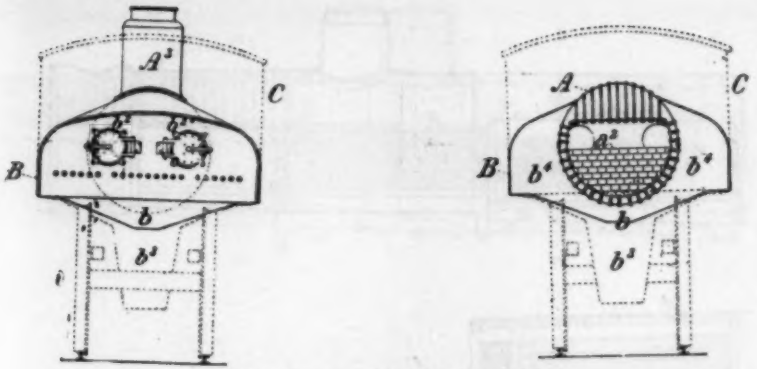




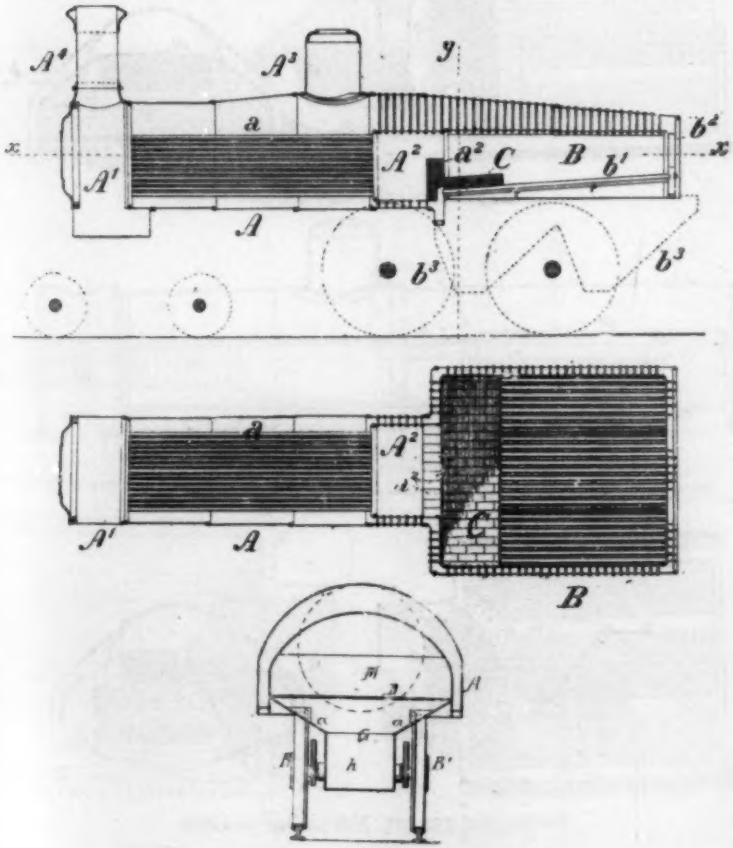
Patent No. 192,725, July 3, 1877.



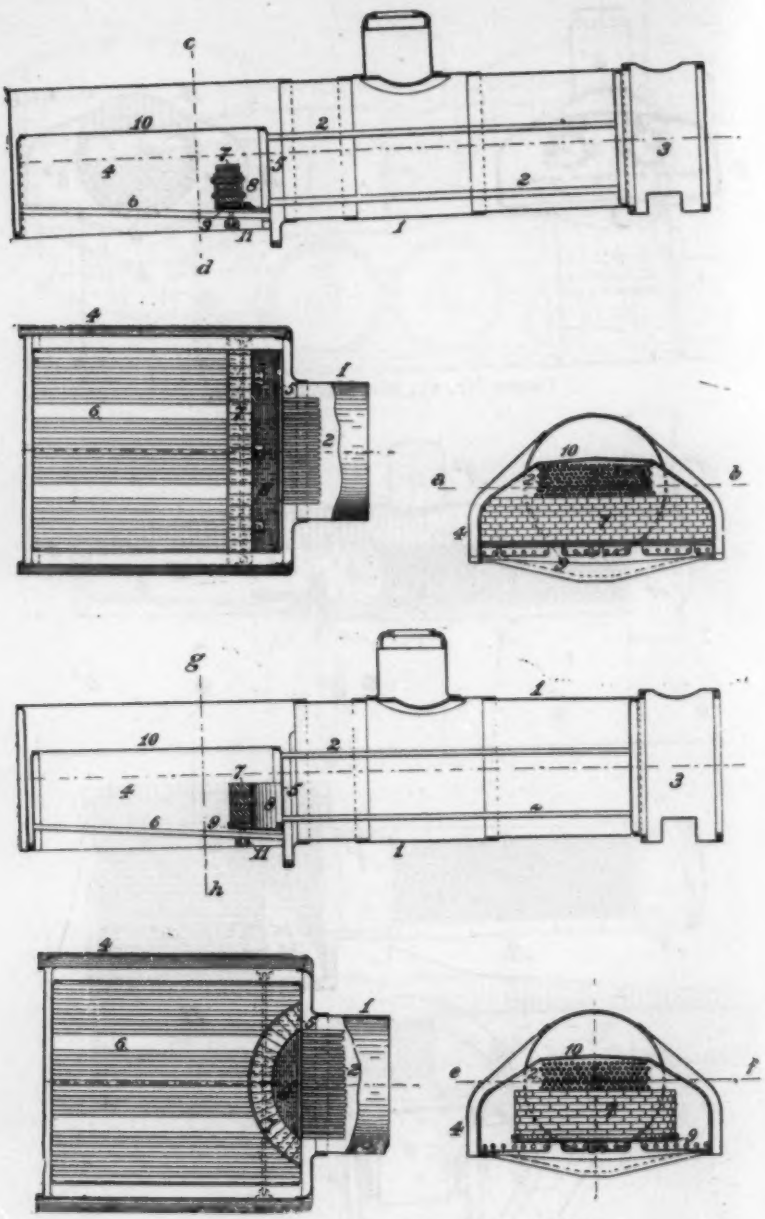
Patent No. 254,581, March 7, 1882.



Patent No. 254,581, March 7, 1882.



Patent No. 291,210, January 1, 1884.



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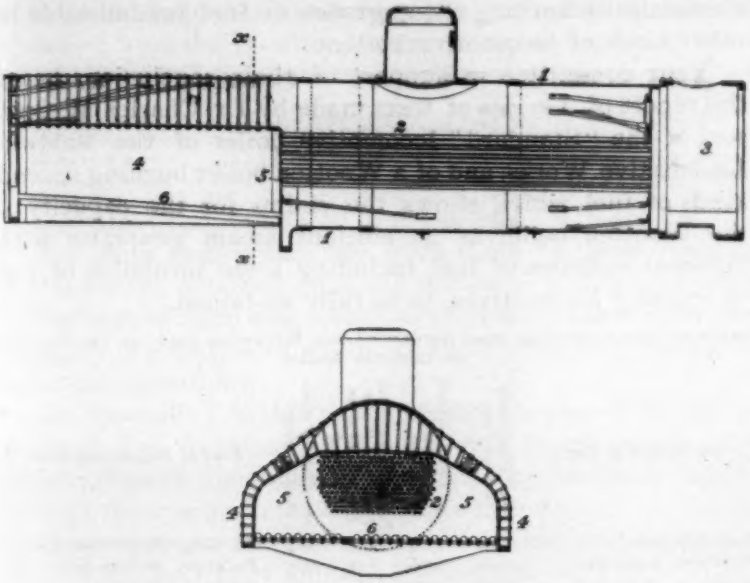
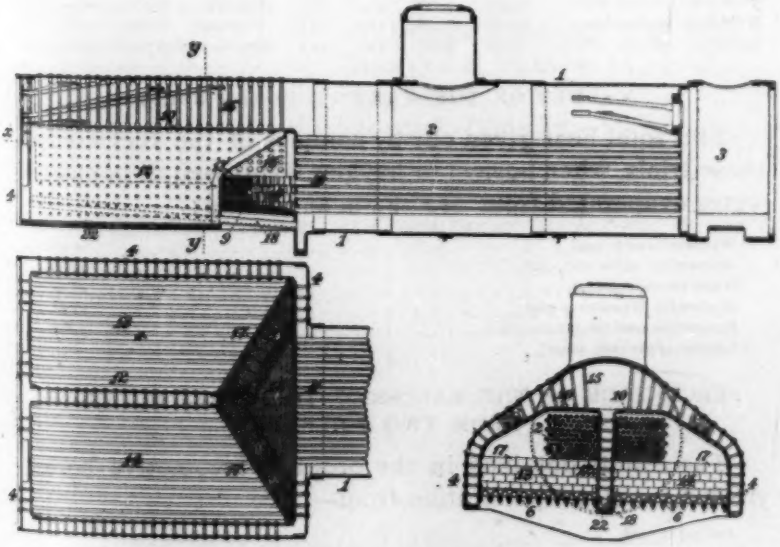


Patent No. 354,370, December 14, 1886.



Patent No. 361,661, April 19, 1887.

economically burning cheap grades of fuel inadmissible in other kinds of locomotive boilers.

Your committee in support of their conclusions quote the report of a series of tests made by Dr. Charles M. Cresson, of the "Standard" locomotive boiler of the Baldwin Locomotive Works, and of a Wootten boiler burning several kinds of fuel, which shows the claims for the capacity of the Wootten boiler as an efficient steam generator with different varieties of fuel, including some incapable of use in ordinary locomotives, to be fully sustained.

TABLE OF RESULTS OBTAINED FROM ANTHRACITE AND BITUMINOUS COALS IN THE WOOTTEN AND ORDINARY BOILERS.

Description of Coals.	*Total Heat Units in Fuel Used.*	*Heat Units Utilized in Generating Steam.*	*Total Equivalent in Pounds of Water Evaporated from 212° F.*	*Per Cent. of Total Heat Utilized.*	*Kind of Engine and Boiler.*
Anthracite, waste,	11,275	7,823	8·09	69·4	Frt. Consolidation Wootten boiler.
Anthracite, marketable,	11,913	7,813	8·08	65·5	Passenger. Wootten boiler.
Anthracite, marketable,	11,275	5,647	5·84	50·0	Passenger. Ordinary boiler.
Bituminous, waste,	12,764	8,209	8·49	64·3	Frt. Consolidation Wootten boiler.
Bituminous, marketable,	13,402	9,302	9·62	69·4	Frt. Consolidation Wootten boiler.
Bituminous, marketable,	13,402	7,397	7·65	55·2	Frt. Consolida'n Ordinary boiler.
Bituminous, marketable,	13,363	9,138	9·45	68·3	Passenger. Wootten boiler.
Bituminous, marketable,	13,731	7,416	7·67	54·0	Passenger. Ordinary boiler.
Lignite, 20 per cent. water,	7,871	3,316	3·43	42·1	Frt. Consolidation Wootten boiler.

VALUES OF THE VARIOUS FUELS USED.

The total heat given out by samples of the fuel used in these trials, when burned in oxygen, expressed in pounds of water evaporated from 212° F., is as follows:

	Pounds.
Waste anthracite coal,	11·66
Marketable anthr cite coal,	12·98
Waste bituminous coal,	13·20
Marketable bituminous coal,	14·86
Marketable semi-bituminous coal,	13·86
Lignite (20 per cent. water),	8·41

PERCENTAGE OF THE VALUES OF THE COALS OBTAINED FROM TWO BOILERS.

The results obtained in the ordinary locomotive boiler, yielded for steam generation from—

	Per Cent.
Anthracite coal,	50·0
Bituminous coal,	54·0
Semi-bituminous coal,	55·2

of the total heat obtainable from the fuel; and the results obtained from the Wootten boiler, which is adapted to burn waste coal, yielded for steam generation with—

	Per Cent.
Anthracite waste,	69·4
Marketable anthracite,	65·5
Bituminous waste,	64·3
Bituminous lump,	68·3

of the total heat obtainable from the fuel.

The data from which the work done by these fuels is derived were obtained from the results of continuous daily operations, of such magnitude as to remove them from the category of experiment and place them upon the footing of practical operations.

An appendix* to this report contains copies of the specifications and drawings of the several letters-patent and illustrations of the engines as in use, together with details of their dimensions, etc., and reports of tests.

In view of the excellent results demonstrated by invention under tests, fully confirmed by several years of practical use, your committee consider it proper to recommend the award to John E. Wootten, of the John Scott Legacy Premium and Medal.

S. Lloyd Wiegand, *Chairman*,
Samuel F. Prince, Jr.,
Luther L. Cheney,
John E. Codman,

Adopted December 3, 1890.

H. R. Heyl,
Chairman (pro tem.) of Committee on Science and the Arts.

* Not published, but accessible on application to the Secretary.

EYESIGHT: ITS CARE DURING INFANCY AND YOUTH.

BY L. WEBSTER FOX, M. D.

[*A lecture delivered before the Franklin Institute, December 5, 1890.*]

The lecturer was introduced by Prof. Edwin J. Houston, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Medical science, as taught in our medical colleges to-day, has two objects in view: (1) the prevention of disease; (2) the amelioration of disease and its cure. Some of our advanced thinkers are suggesting a new mode of practice; that is, the prevention of disease by proper hygienic measures. Chairs are being established and professors appointed to deliver lectures on hygiene. Of what value is the application of therapeutics if the human economy is so lowered in its vital forces that dissolution is inevitable. Is it not better to prevent disease than to try the cure after it has become established, or has honey-combed the constitution?

These few preliminary remarks are *apropos* to what is to follow in the subject which I have selected as the topic for discussion this evening.

Vision is the most useful of all the senses. It is the one gift which we should cherish and guard the most. And at no time in one's life is it more precious than in infancy and youth.

In infancy, when the child is developing, the one great avenue to the unfolding, or more properly speaking, the development, of the intellect is through the eye. The eye at this period holds in abeyance all the other senses. The child, when insensible to touch, taste, smell or hearing, will become aroused to action by a bright light or bright colors, or the movement of any illuminated object, proving to all that light is essential to the development of the first and most important sense. Again, the infant of but six days

of age will recognize a candle flame, while its second sense and second in importance to its development—hearing—will not be recognized for *six* weeks to two months. Taste, touch and smell follow in regular sequence. Inasmuch as light makes thus early an impression on the delicate organ of vision how necessary it behooves us to guard the infant from too bright lights or too much exposure in our bright climate. Mothers—not only the young mother with her first child—but also those who have had several children, are too apt to try to quiet a restless child by placing it near a bright flame; much evil to the future use of those eyes is the outgrowth of such a pernicious habit. Light throws into action certain cells of that wonderful structure of the eye, the retina, and an over-stimulus perverts the action of those cells. The result is that by this over-stimulation the seeds of future trouble are sown. Let the adult gaze upon the arc of an electric light or into the sun, and for many moments, nay hours, that individual has dancing before his vision scintillations and phosphenes. His direct vision becomes blurred, and, as in the case of a certain individual I have in mind, there may be a permanent loss of sight. Parents should take the first precaution in the child's life, and not expose it to a light too bright or glaring. When in the open air let the child's eyes be protected from the direct rays of the sun. While it is impossible to give all children the advantage of green fields and out-door ramblings, yet nature never intended that civilization should debar the innocent child from such surroundings.

An anecdote is related of a French ophthalmic surgeon, that a distinguished patient applied to him for relief from a visual defect; the surgeon advised him to go into the country and look out upon the green fields; the green color with its soothing effect soon brought about a restoration of vision. What I wish to illustrate by this anecdote is that children should be allowed the green fields as their best friend in early life, it tones up the system and rests the eye. After out-door exercise and plenty of it, we should turn our attention to the home surroundings of our little ones. The over-heated rooms of the average American

home I am sure have more to do with the growing tendency of weak eyes than we feel like admitting. Look at these frail hot-house plants and can anyone believe that such bodies nourished in almost pestilential atmosphere can nourish such delicate organs of vision, and keep them ready for the enormous amount of work each little eye performs daily. The brain developing so rapidly wills with an increasing rapidity the eye to do increasing duties—note the result—a tendency to impoverished circulation first, and the eye with its power to give the brain a new picture in an infinitesimal short space of time means lightning-like circulation—the eye must give way by its own exhaustion.

Civilization is the progenitor of many eye diseases.

After a boy has grown to that age when it becomes necessary for him to begin the education prescribed by the wise men, obstacles are placed in his way to aid again in causing deterioration of vision. It is not so much the overcrowded condition of our school-rooms as the enormous amount of work, that causes deterioration of sight. Our children begin their school-life at a time when they are too young. A child at six years of age who is forced to study all day or even a part of a day will not run the same race that one will who commences his studies at ten—all things being equal. The law prescribes that so much time must be devoted to study, so many forms must be passed, so many books must be read, so many pages of composition written—all probably in badly-lighted rooms, or by artificial light. Note the effect. First, possibly, distant vision gives way; the teacher, sympathizing with the over-burdened child, tries to make the burden lighter by changing his position in the room or placing him under the cross-light from a window; as the evil progresses the child is taken to an ophthalmic surgeon and the inevitable result—glasses—rightly called "crutches for the eyes" are given. What would be thought of a cause which would weaken the legs of that boy so that he would have to use crutches to carry him through life? If civilization be responsible for an evil, let our efforts be put forth in finding a remedy for that evil.

A discussion, in a recent number of the *British Medical*

Journal,* on "The Claims and Limitations of Physical Education in Schools," has many valuable hints which should be followed by educators in this country. Dr. Carter, in the leading paper on this subject, makes the pregnant remark, "If the hope is entertained of building up a science of education, the medical profession must combine with the profession of teaching, in order to direct investigation and to collect material essential to generalization. Without such co-operation educational workers must continue to flounder in the morasses of empiricism, and be content to purchase relative safety at the cost of slow progress, or no progress at all." In other words, an advisory medical board should co-exist with our board of public education, to try to hold in check or prevent a further "cruelty in trying to be kind." Private institutions of education recognize the importance of physical training and development, and in such institutions the deterioration of vision is in proportion, less than in institutions where physical training is not considered. In one school of over 200 middle class girls, Dr. Carter found that, during a period of six years, no fewer than ten per cent. of the total number of girls admitted during that time, have been compelled to take one or more terms' leave of absence, and of the present number twenty-eight per cent. have medical certificates exempting them from gymnastic exercise and 10·25 per cent. of the total present number wear eye-glasses of some kind or other. From my own experience the same number of students in our schools would show about the same percentage of visual defects. These questions are of such growing importance that not only instructors, but the medical fraternity should not rest until these evils are eradicated.

Dr. J. W. Ballantyne, of Edinburgh, in a lecture† on diseases of infancy and childhood, says: "The education of the young people of a nation is to that nation a subject of vital importance." The same writer quotes the startling statement made by Prof. Pflüger, that of 45,000 children

* Nov. 1, 1890.

† *Lancet*, Nov. 1, 1890.

examined in Germany more than one-half were suffering from defective eyesight, while in some schools the proportion of the short-sighted was seventy or eighty per cent., and, crowning all, was the Heidelberg Gymnasium, with 100 per cent. These figures, the result of a careful examination, are simply startling, and almost make one feel that 'twere better to return to the old Greek method of teaching by word of mouth.

Prof. Pflüger attributes this large amount of bad sight to insufficient lighting of school-rooms, badly printed books, etc. One must agree with a certain writer, who says: "Schools are absolute manufactories of the short-sighted, a variety of the human race which has been created within historic time, and which has enormously increased in number during the present century." Granting that many predisposing causes of defective vision cannot be eliminated from the rules laid down by our city fathers in acquiring an education, it would be well if the architects of school buildings would bear in mind that light when admitted into class-rooms should not fall directly into the faces of children, but desks should be so arranged that the light must be sufficiently strong and fall upon the desk from the left hand side. My attention has repeatedly been called to the cross lights in a school-room. The light falling directly into the eyes contracts the pupil which is already contracted by the action of the muscle of accommodation in its effort to give a clearer picture to the brain. This has a tendency to elongate the eye-ball, and as a permanent result we have near-sightedness. Where the eye-ball has an unnatural shortness this same action manifests itself by headaches, chorea, nausea, dyspepsia, and ultimately a prematurely breaking-down of health. The first symptom of failing sight is a hyper-secretion of tears, burning of the eye-lids, loss of eye-lashes, and congestion either of the eye-lids or the eye-ball proper.

The natural condition of aboriginal man is far-sighted. His wild life, his nomadic nature, his seeking for game, his watching for enemies, his abstention from continued near work, have given him this protection. Humboldt speaks of

the wonderful distant vision of the South American Indians; another traveller in Russia of the power of vision one of his guides possessed, who could see the rings of Saturn. My recent examinations among Indian children of both sexes also confirm this. While the comparison is not quite admissible, yet the recent investigations carried on by Lang and Barrett, who examined the eyes of certain mammalia, found that the larger number were hypermetropic or far-sighted. With all the difficulties which naturally surround such an examination they found that in fifty-two eyes of rabbits, thirty-six were hypermetropic and astigmatic, eight were hypermetropic only, five were myopic and astigmatic, and others presented mixed astigmatism. In the eyes of the guinea pig about the same proportion of hypermetropia existed. The eyes of five rats examined gave the following result: Some were far-sighted, others were hypermetropic and astigmatic, one was slightly myopic and one had mixed astigmatism. Of six cows, five were hypermetropic and astigmatic and one was slightly myopic.

Six horses were also examined, of which one had normal sight, three were hypermetropic and astigmatic, and two had a slight degree of astigmatism. They also examined other animals and the same proportion of hypermetropia existed. These gentlemen found that as an optical instrument the eye of the horse, cow, cat and rabbit, is superior to that of the rat, mouse and guinea pig.

I have for the last five years devoted considerable attention to the vision of the Indian children who are pupils at two institutions in this city. I have at various times made careful records of each individual pupil and have from time to time compared them. Up to the present there is a growing tendency towards myopia or short-sightedness, *i. e.*, more pupils from year to year require near-sighted glasses. The natural condition of their eyes is far-sighted and the demands upon them are producing many nervous or reflex symptoms, pain over the frontal region and head-aches. A good illustration of the later trouble is showing itself in a young Indian boy, who is at present undergoing an examination of his vision as a probable cause for his

headaches. This boy is studying music; one year ago he practised two hours daily on the piano and studied from three to five hours besides. This year his work has been increased; he is now troubled with severe headaches, and after continued near work for some time letters become blurred and run together. This boy is far-sighted and astigmatic; glasses will correct his defect, and it will be interesting to note whether his eyes will eventually grow into a near-sighted one. I have several cases where the defective vision has been due entirely to other causes, such as inflammation of the cornea, weakening this part of the eye, and the effect in trying to see producing an elongation of the anterior portion of the eyeball, and this in turn producing myopia. The eye of the Indian does not differ materially from that of any deeply pigmented race. The eyeball is smaller than in the Caucasian, but when we examine the interior we find the same distribution of the blood-vessels and same shape of the optic nerves. The pigment deposit in the choroid is excessive and gives, as a background to the retina, a beautiful silvery sheen when examined with the ophthalmoscope. One thing which I noticed particularly was the absence of this excessive deposit of pigment and absence of this watered-silk appearance in the half-breeds, they taking after the white race.

The absence of many of the intraocular diseases common among the white children were also absent, especially those diseases which are the result of near work.

It is a well-known fact among breeders of animals, that where animals are too highly or finely bred the eye is the organ first to show a retrogression from the normal. In an examination by myself some years ago among deaf mutes, I found the offspring of consanguineous marriages much affected and while not only were many afflicted with inflammatory conditions of the choroid and retina; their average vision was much below the normal.

My quoting Messrs. Lang and Barrett's figures was to bring more prominently to the notice of my hearers the fact that the eyes of primitive man resembled the eyes of the lower mammalia and that the natural eye as an organ of vision was

hypermetropic, or far-sighted, and that civilization was the cause of the myopic or near-sighted eye. Nature always compensates in some way. I grant that the present demands of civilization could not be filled by the far-sighted eye but the evil which is the outgrowth of present demands does not stop when we have reached the normal eye, but the cause once excited, the coats of this eye continue to give way and myopia or a near-sighted condition is the result.

Among 300 Indians examined, I found when I got to the Creeks, a tribe which has been semi-civilized for many years, myopia to be the prevailing visual defect.

Without going into statistics I am convinced from my experience that the State must look into this subject and give our public school system of education more attention, or we as a people will soon be known as a "spectacled race."

Myopia or short-sightedness among the Germans is growing at a tremendous rate. While I do not believe that the German children perform more work than our own children, there is one cause for this defect which has never been touched upon by writers, and that is the shape of the head. The broad flat face or German type, as I would call it, has not the deep orbit of the more narrow, sharp-featured face of the American type. The eye of the German standing out more prominently and in consequence less protected, is thereby more prone to grow into a near-sighted eye. One of the significant results of hard study was recently brought to my notice by looking over the statistics on the schools of Munich in 1889. In those schools 2,327 children suffered from defective sight, 996 boys and 1,331 girls.

Of 1,000 boys, in the first or elementary class, 36 are short-sighted; in the second, 49; in the third, 70; in the fourth, 94; in the fifth, 108; in the sixth, 104; and in the last and seventh, 108. The number of short-sighted boys, therefore, from the first class to the seventh, increases about threefold. In the case of the girls, the increase is from 37 to 119.

These statistics in themselves show us the effects of overwork, incessant reading or study by defective gas- or lamp-light, or from an over-stimulating light, as the arc light,

late hours, dissipation and frequent rubbing of the eye, also fatigue, sudden changes from darkness to light, and what is probably worse than all, reading on railway trains. The constant oscillations of the car cause an over-activity of the muscle of accommodation which soon becomes exhausted, the brain willing the eye to give it a clear photograph continues to force the ciliary muscle, which muscle governs the accommodation, in renewed activity, and the result may easily be foretold.

The fond parents finding that the vitiated air of the city is making their once rosy-cheeked children turn pale, seek a remedy in the fresh air of the country; the children find their way to city schools; this necessitates travelling so many miles a day in railway cars; the children take this opportunity of preparing their studies while en route to the city, and here is where they get their first eye-strain. Children have the example set them by their parents or business men who read the daily papers on the trains. Children are great imitators, and when their attention is called to the evil, quote their parents' example and they follow it. No wonder each generation is growing more effeminated.

The light in sick rooms should never fall directly on the eyes, nor should the rooms be either too dark or too light.

The Esquimaux and Indians long ago noted the fact that sunlight reflected from freshly-fallen snow would soon cause blindness.

The natives of Northern Africa blacken themselves around the eyes to prevent ophthalmia from the glare of the hot sand. In Fiji, the natives when they go fishing blacken their faces. My friend, Dr. Bartelott, presented me with a pair of eye protectors which he brought from Alaska. The natives use them to protect themselves from snow-blindness. These snow spectacles, or snow eyes, as they are called, are usually made out of pine wood which is washed upon their shores, drift-wood, from southern climes.

The posterior surface is deeply excavated to prevent its

obstructing the free motion of the eye-lids, on each side a notch is cut at the lower margin to allow a free passage for the tears. The upper margin of the front surface is more prominent than the under to act as a shade to the eyes. The inner surface is blackened to absorb the excessive light. The openings are horizontal slits. The eyes are thus protected from the dazzling effect of the light.

My friend Dr. Grady, of Omaha, communicated to me a history of three hunters who almost lost their eyesight by too long exposure to the bright rays of the sun falling on snow.

The abuse of tobacco leads to impairment of vision in the growing youth. Cigarette smoking is an evil. I am inclined to believe that the poisons inhaled arrest the growth of boys; surely it prevents a mental development, and when carried to excess affects vision more by lessening the power of nerve conduction, than acting directly on the eye.

It is not the one cigarette which the boy smokes that does the harm, but it is the one, two or three packages smoked daily. This excessive smoking thoroughly perverts all the functions which should be at their best to aid this growing youth. First we have failing digestion, restless nights, suspension of growth, lack of mental development, the loss of nerve tone, loss of the power of accommodation in vision, failing sight, headaches, enfeeblement of the heart. Let a man who is a habitual smoker of cigars attempt to smoke even one package of cigarettes and he will complain of nausea, dry throat and loss of appetite. If a strong man is so much affected by this poison, how much less can a boy resist the inroads of such poisons. In Germany the law forbids the sale of cigarettes to growing boys. New York State has a similar law, and why should our own or any other State be behind in passing prohibitory laws against this evil; and this is a growing evil.

I have never seen a case of tobacco amblyopia in boyhood, but such a condition is not infrequent in adults. In boys the action of nicotine acts especially upon the heart, the impulse is rendered weaker and intermittent and many

young boys lay the seeds of organic disease which sooner or later culminates fatally. Boys should be prohibited from smoking, first by their parents, second by law, but not such laws whose enforcement is a failure, third by placing a heavy fine upon dealers who sell to minors. The pernicious evil of intoxication is no less an evil upon the nervous system of a youth than is the habit of cigarette smoking, but fortunately this habit is less common. Having traced from aboriginal man to the present civilized individual the cause of his myopia, what must we do to prevent a further deterioration of vision? Unfortunately, the physician of our country is not, as I am told, like the Japanese physician. Our medical men are called to attend people who are ill and to try to get them well—the Japanese physician is paid only to keep his patients in health.

The first effort parents should make is to see that their children have plenty of out-door exercise. Good warm clothing in winter and light-texture cloth in summer. A great difference of opinion exists as to the age at which a child should begin its studies. I feel sure that the boy who commences his studies at ten will far outrun the one who commences study at six. Every child should commence his lessons in the best kindergarten, the nursery. Let object lessons be his primer—let him be taught by word of mouth —then, when his brain is what it should be for a boy of ten, his eyes will be the better able to bear the fatigue of the burdens which will be forced upon him. Listen to what Milton has left on record as a warning to those young boys or girls who insist upon reading or studying at night with bad illumination.

"My father destined me, from a child, for the pursuits of polite learning, which I prosecuted with such eagerness that, after I was twelve years old, I rarely retired to bed, from my lucubrations, till midnight. This was the first thing which proved pernicious to my eyes, to the natural weakness of which were added frequent headaches." Milton went blind when comparatively a young man, and it was always to him a great grief. Galileo, the great astronomer, also went blind by overwork. It was written of him, "The

noblest eye which ever nature made is darkened—an eye so privileged, and gifted with such rare powers, that it may truly be said to have seen more than the eyes of all that are gone, and to have opened the eyes of all that are to come."

When the defect of far-sightedness or near-sightedness exists, we have but one recourse—*spectacles.*

Some time ago I published, in the *Medical and Surgical Reporter*, an article on the history of spectacles. The widespread interest which this paper created has stimulated me to continue the research and since this article appeared I have been able to gather other additional historical data to what has been described as an invention for "poor old men when their sight grows weak."

The late Wendell Phillips, in his lecture on the "Lost Arts," speaks of the ancients having magnifying glasses. "Cicero said that he had seen the entire *Iliad*, which is a poem as large as the New Testament, written on a skin so that it could be rolled up in the compass of a nut-shell;" it would have been impossible either to have written this, or to have read it, without the aid of a magnifying glass.

In Parma, a ring 2,000 years old, is shown which once belonged to Michael Angelo. On the stone is engraved the figures of seven women. You must have the aid of a glass in order to distinguish the forms at all. Another *intaglio* is spoken of—the figure is that of the god Hercules; by the aid of glasses, you can distinguish the interlacing muscles and count every separate hair on the eyebrows." Mr. Phillips again speaks of a stone 20 inches long and 10 wide containing a whole treatise on mathematics, which would be perfectly illegible without glasses. Now, our author says, if we are unable to read and see these minute details without glasses, you may suppose the men who did the engraving had pretty strong spectacles.

"The Emperor Nero, who was short-sighted, occupied the imperial box at the Coliseum, and, to look down into the arena, a space covering six acres, the area of the Coliseum, was obliged, as Pliny says, to look through a ring with a gem in it—no doubt a concave glass—to see more clearly the sword play of the gladiators. Again, we read of

Mauritius, who stood on the promontory of his island and could sweep over the sea with an optical instrument to watch the ships of the enemy. This tells us that the telescope is not a modern invention."

Lord Kingsborough, speaking of the ancient Mexicans, says: "They were acquainted with many scientific instruments of strange invention, whether the telescope may not have been of the number is uncertain, but the thirteenth plate of *Dupaix's Monuments*, part second, which represents a man holding something of a similar nature to his eye, affords reason to suppose that they knew how to improve the powers of vision."

*Our first positive knowledge of spectacles is gathered from the writings of Roger Bacon, who died in 1292. Bacon says: "This instrument (a plano-convex glass or large segment of a sphere) is useful to old men and to those who have weak eyes; for they may see the smallest letters sufficiently magnified."

Alexander de Spina, who died in 1313, had a pair of spectacles made for himself by an optician who had the secret of their invention. De Spina was so much pleased with them that he made the invention public.

Monsieur Spoon fixes the date of the invention between 1280 and 1311. In a manuscript written in 1299 by Pissazzo, the author says: "I find myself so pressed by age that I can neither read nor write without those glasses they call spectacles, lately invented, to the great advantage of poor old men when their sight grows weak." Friar Jordan, who died in Pisa in 1311, says in one of his sermons, which was published in 1305: "That it is not twenty years since the art of making spectacles was found out, and is indeed one of the best and most necessary inventions in the world." In the fourteenth century spectacles were not uncommon and Italy excelled in their manufacture. From Italy the art was carried into Holland, then to Nuremberg, Germany. In a church in Florence is a fresco representing St. Jerome (1480). Among the several things represented is an ink-

* *Med. and Surg. Reporter.*

horn, pair of scissors, etc. We also find a pair of spectacles, or *pince-nez*—the glasses are large and round and framed in bone.

It was not until 1575 that Maurolicus of Messina pointed out the cause of near-sightedness and far-sightedness and explained how concave glasses corrected the former, and convex glasses the latter defect.

In the wake of advanced education stalks the spectacle age. Any one watching a passing crowd cannot fail but note the great number of people wearing spectacles. Unfortunately it is not limited to adults, but our youths of both sexes go to make up this army of ametropes.

At what age should children first wear glasses? This is a much debatable question. Where there is simply a defect of vision I should never prescribe a pair of glasses for a child under ten years of age. A child under this age runs many risks of injury to the eyeball by accident to the glasses, and to cut the eye with glass is a very serious affair. Rather let a child go without study, or even with impaired vision, than run the risk of a permanent loss of sight.

Another source of evil I must call your attention to, and that is the indiscriminate use of glasses given by itinerant vendors of spectacles who claim a thorough knowledge of the eye, who make examination free, but charge double price for glasses.

Persons, before submitting themselves into the hands of opticians, should know that they are not suffering from any incipient disease of their eyes. I do not, for a moment, claim that a practical optician cannot give you a pair of glasses which will make you see—he does nothing more than hand you a number of pairs of glasses and you select the one pair which you think answers the purpose. How can any one but a medical man know that the impairment of vision does not arise from diminished sensibility of the retina? If so, the glasses just purchased, which may be comfortable for a time, may cause an irreparable loss of vision. Every ophthalmic surgeon will tell you that he has had a number of such cases. Do not be misguided by purchasing cheap spectacles. Glasses advertised as having

"remarkable qualities" are always to be passed by. They have "remarkable qualities;" they always leave the person wearing them worse at the end of a few months. Whenever an eye finds relief in a shaded or colored glass, something is going wrong with the interior of that eye. Seek advice, but do not trust the eyes of yourself, much less those of your children, in the hands of the opticians who advertise their examinations free.

Such individuals should be brought before a tribunal, and the matter sifted as to whether the sense of sight is less to be taken care of than if that same patient were ill with pneumonia and a druggist were to prescribe remedies which might or might not aid this patient. If one man must comply with the law, why should not the other? Our medical colleges are lengthening the course of studies; the advances in the various departments of science demand this. It is by the aid of the ophthalmoscope that many obscure diseases are diagnosed, and while it is impossible for every young man who obtains a diploma to become thoroughly proficient in the use of this instrument, yet the eye shows to him many conditions which guide him to the road of successful treatment. Think of a case of optic neuritis—inflammation of the optic nerve—going to an optician and fitting one set of glasses after another until the patient suddenly discovers that blindness is inevitable. Many individuals, and very intelligent ones at that, think that so long as a glass makes them see, that is all they need. When we know that scarcely two eyes are alike, we can at once feel that it is very important that each eye should be properly adjusted for a glass; by this we are sure of having comfort in reading and preserving vision.

There is a very important defect in vision which should be detected as early in life as possible, and that is color-blindness. The boy who is a color-blind will always remain a color-blind, and as forty in every 1,000 of the male sex are color-blind, it is essential that they know their defect, and train their course accordingly. It would be to the advantage of all boys to undergo such an examination once in their school-life; a color-blind would be useless where

the selection of color entered into his life-work. If a boy had a talent for drawing or engraving, and were color-blind he would make a success of his life, whereas if he would attempt to mix paints of different colors he would be a failure.

I shall not dwell upon the scientific part of color-blindness, nor discuss either the Young-Helmholtz or the Hering theories of color defect, but shall deal with its practical use in every-day life.

Until the year 1853, very little was known about color-blindness, and much less written about it.

Dr. George Wilson, in 1853, wrote several articles, which were published in the *Edinburgh Monthly Journal of Medical Science*. These articles created such an interest in the scientific world that Dr. Wilson brought out a book, entitled *Researches on Color-Blindness*, two years later. So thoroughly did Dr. Wilson sift this subject that no writer up to the present day has added anything practical to what was then known.

Dr. Wilson writes in his preface: "The most practical relation of color-blindness is that which it has to railway and ship signals. He further states: "The professions for which color-blindness most seriously disqualifies are those of the sailor and railway servant who have daily to peril human life and property on the indication which a colored flag or a lamp seems to give."

Dr. Bickerton, in an article on this same subject, speaking of the careless way in which lights were used on ships at sea, says: "Until the year 1852, there were no definite rules regarding the carrying of lights at night by vessels at sea. * * * At this time the subject of color-blindness had not awakened the attention of practical observers, and had the fact been known that between three and four per cent. of the whole male population are color-blind, some other mode might have been devised to indicate the positions of vessels at night than by showing red and green lights.

If it is so very important to have sailors with good color perception, where, at least, four men are on the lookout,

how much more important is it to have our engine drivers with perfect color perception, where one man alone watches the signal of safety or danger. The growth of our railway system is constantly increasing. We have to-day probably 150,000 men employed in this service. The boys attending public schools to-day in a few years will have to fill the ranks of these men. How important for these boys to know that they have not this defect. If the forty boys in every 1,000 are found, what is to be done with them? The engraver, the wood-cut engraver, the etcher, all wish apprentices. I am also informed that these occupations pay well. It requires talent to fill them, and here is an opening for the color-blind. Hear what a color-blind writes:* "I beg to offer some particulars of my own case, trusting it may be of use to you. I am an engraver, and, strange as it may appear, my defective vision is, to a certain extent, a useful and valuable quality. Thus, an engraver has two negative colors to deal with, *i. e.*, white and black. Now, when I look at a picture, I see it only in white and black, or light and shade, and any want of harmony in the coloring of a picture is immediately made manifest by a corresponding discord in the arrangement of its light and shade or as artists term it, the *effect*. I find at times, many of my brother-engravers in doubt how to translate certain colors of pictures, which to me are matters of decided certainty and ease. Thus, to me it is valuable." Having already spoken about the importance of having all boys undergo an examination for color-blindness once in their school-lives, we have two very good reasons for making this suggestion.

First, prevent a boy following a trade or occupation where he is incapacitated, and, secondly, let him be trained for a certain trade or occupation when the defect exists. The savage races possess the perception of color to a greater degree than do civilized races. I have just concluded an examination of 250 Indian children; 100 were boys. Had I selected 100 white boys from various parts of the United States I would have found at least five color-blinds; among

* Wilson, p. 27.

the Indian boys I did not find a single one. Some years ago I examined 250 Indian boys and found two color-blind, a very low percentage when compared with the whites. Among the Indian girls I did not find any. When we know that only two females in every 1,000 among whites are color-blind, it is not surprising that I did not find any examples among the Indian girls.

The usual tests for color-blindness are the matching of wools; the common error the color-blind falls into is matching a bright scarlet with a green. On one occasion, a color-blind gentleman found fault with his wife for wearing, as he thought, a bright scarlet dress, when in point of fact, she was wearing a bright green. Another color-blind who was very fond of drawing, once painted a red tree in a landscape without being aware that he had done so.

Among the whites it affects all classes. It is found as relatively common among the intelligent as the illiterate, and unfortunately, up to the present, we have not discovered any remedy for this defect.

Without quoting many instances where a color-blind man was responsible for accidents at sea, I must quote a case where an officer on the watch issued an order to "port" his vessel, which, if his order had been carried out, would have caused a collision, and a probable serious loss of life.

The letter was written by Capt. Coburn, and is to be found in the *Mercantile Marine Reporter*, vol. xiv.

"The steamer *Neera* was on a voyage from Liverpool to Alexandria. One night, shortly after passing Gibraltar, at about 10.30 P.M., I went on the bridge, which was then in charge of the third officer, a man of about forty-five years of age, and who up to that time I had supposed to be a trustworthy officer, and competent in every way. I walked up and down the bridge until about 11 P.M., when the third officer and I almost simultaneously saw a light about two points on the starboard bow. I at once saw it was a green light, and knew that no action was called for. To my surprise, the third officer called out to the man at the wheel, 'port,' which he was about to do, when I countermanded the order, and told him to steady his helm, which he did,

and we passed the other steamer safely about half a mile apart. I at once asked the third officer why he had ported his helm to a green light on the starboard bow, but he insisted it was a red light which he had first seen. I tried him repeatedly after this, and although he sometimes gave a correct description of the color of the light, he was as often incorrect, and it was evidently all guesswork. On my return, I applied to have him removed from the ship, as he was, in my opinion, quite unfit to have charge of the deck at night and this application was granted. After this occurrence I always, when taking a strange officer to sea, remained on the bridge with him at night until I had tested his ability to distinguish colors. I cannot imagine anything more dangerous or more likely to lead to fatal accidents than a color-blind man on a steamer's bridge."

A similar experience is thus related by Capt. Heasley, of Liverpool: "After passing through the Straits of Gibraltar, the second officer, who had charge of the deck, gave the order to 'port,' much to my astonishment, for the lights to be seen about a point on the starboard bow were a mast-head and green light, but he maintained that it was a mast-head and red, and not until both ships were nearly abreast would he acknowledge his mistake. I may add that during the rest of the voyage I never saw him making the same mistake. As a practical seaman I consider a great many accidents at sea arise from color-blindness."

Dr. Farquharson has brought this subject before the House of Commons in England and measures are being taken which will insure to the travelling public immunity from accidents at sea. I need not mention that the majority of railways of our country have a system of examinations which prevents a color-blind entering their service.

Dr. Wilson makes the suggestion that he noticed a singular expression in the eyes of certain of the color-blind difficult to describe. "In some it amounted to a startled expression, as if they were alarmed; in others, to an eager, aimless glance, as if seeking to perceive something but unable to find it; and in certain others to an almost vacant stare, as if their eyes were fixed upon objects beyond the limit of

vision. The expression referred to, which is not at all times equally pronounced, never altogether leaves the eyes which it seems to characterize."

Dr. B. Joy Jeffries, of Boston, has recently written an article on this same topic, but unfortunately I have not his pamphlet at hand to quote his views on this subject.

In this lecture I have shown that the normal eye is far-sighted. The mammalia have this kind of an eye; the Indian the same. The white man is fast becoming near-sighted. The civilized Indian is also showing the effects of continuous near work; and now the question arises, What are we to do to prevent further deterioration of vision? The fault lies at our own doors. Let us try to correct these now existing evils, so that future generations will, instead of censuring us, thank us for our wisdom.

To aid in a feeble way for the protection of posterity I have formulated ten rules on the preservation of vision:

(1) Do not allow light to fall upon the face of a sleeping infant.

(2) Do not allow babies to gaze at a bright light.

(3) Do not send children to school before the age of ten.

(4) Do not allow children to keep their eyes too long on a near object, at any one time.

(5) Do not allow them to study much by artificial light.

(6) Do not allow them to use books with small type.

(7) Do not allow them to read in a railway carriage.

(8) Do not allow boys to smoke tobacco, especially cigarettes.

(9) Do not necessarily ascribe headaches to indigestion, the eyes may be the exciting cause.

(10) Do not allow the itinerant spectacle vendor to prescribe glasses.

NEW CONSTRUCTIONS OF THE FORCE OF INERTIA OF CONNECTING RODS AND COUPLERS, AND CONSTRUCTIONS OF THE PRESSURES ON THEIR PINS.

BY J. F. KLEIN, D.E.
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The constructions and demonstrations are arranged in the following order:

(*a*) Total force accelerating the rod of the ordinary slider crank, when crank has uniform rotation. Two constructions.

(*b*) Total force accelerating the rod of the crossed slider crank, when crank has a variable rotation and centre of gravity of rod is not on centre line of rod. Construction.

(*c*) Resultant of inertia and weight of rod. Construction and demonstration.

(*d*) Pressure on crank-pin and rotative effect when there is no friction at pins. Construction and demonstration.

(*e*) Pressure on crank-pin and rotative effect when there is friction at pins. Construction and demonstration.

(*f*) The accelerations of the pins of the coupler in the quadric chain when one crank has a uniform rotation. Construction.

(*g*) The accelerations of the pins of the coupler in the quadric chain when both cranks have variable rotation. Construction and demonstration.

(*h*) Demonstrations of the constructions given under (*f*) (*b*) and (*a*) and of auxiliary propositions relating to the formation of acceleration images and the determination of the centre of acceleration.

A.

The mechanism OCW is the ordinary slider crank, in which the stroke of the slide W passes through the centre O of the crank OC. The centre of the rod is at A, the centre of gravity at G and $GF = GD$ is the principal polar radius of gyration.

We will first construct the acceleration of the slide *W* by a simple and new method.

Prolong the rod *WC* till it intersects at *B* the perpendicular *OB* to the stroke *OW*. With *C* as a centre and *CB* as a radius describe a circle *Btv*. On the rod *CW* as a diameter describe another circle. Join the intersections of these circles by the chord *tsv* and prolong it, if necessary, till it cuts a line drawn through crank centre *O* and parallel to stroke. In *Figs. 1* and *2* this intersection is at *w*, and *Ow* is the desired acceleration of the slide provided crank length *CO* represents the centripetal acceleration of the uniformly rotating crank-pin.

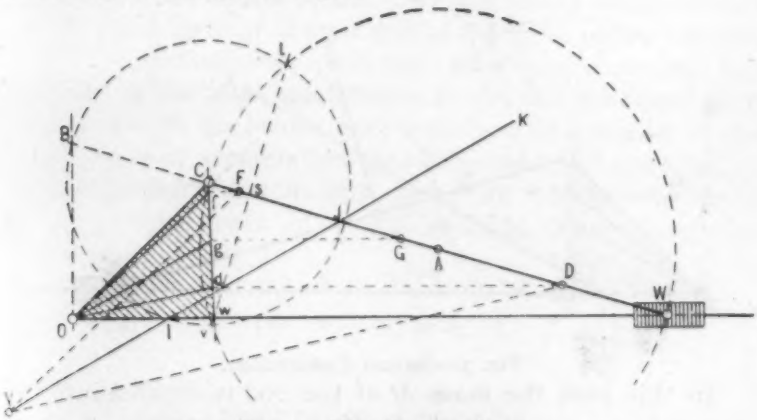

FIG. 1.—First Construction.

(The construction would be exactly the same for the crossed slider crank of *Fig. 3* if its crank had uniform rotation; the acceleration of the slide would then be *Ow*. This construction of the slide acceleration has no failing case even at the dead point.)

Now join *C* and *w*. We will show later that *Cw* is a reduced image of the rod, making with it an angle equal to that made by each point's acceleration with its own radius of acceleration, and we will also show that that point *O* has the same positions relatively to the image *Cw* of the rod that the centre of acceleration has relatively to the rod itself. It follows from this that if we draw through points *F*, *G* and *D* of the rod, parallels *Ff*, *Gg* and *Dd* to the

stroke, that the distances or vectors *Of*, *Og* and *Od* will represent in direction and intensity the accelerations of *F*, *G* and *D*, respectively. The actual location of their accelerations will, of course, be parallels through these points to those vectors. One-half of the mass of the rod is supposed to be concentrated at *F* and the other half at *D*.

Draw *FV* parallel to *Of* and *DV* parallel to *Od*. Through their intersection *V* draw, parallel to *Og*, the line *VK*; it will be the actual location of the resultant force of inertia, and its intensity will equal the product of the whole mass of the rod by acceleration *Og* of the centre of gravity.

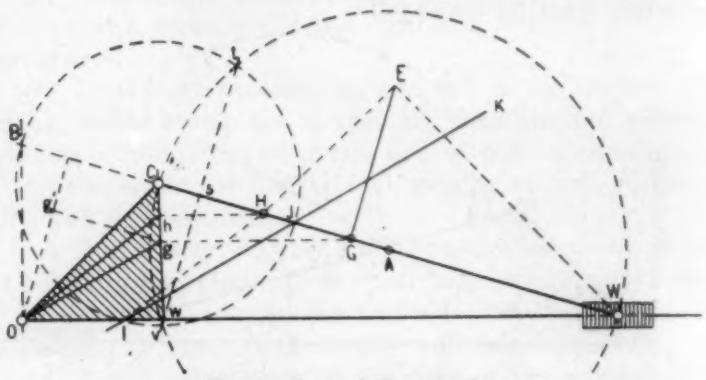

FIG. 2.—Second Construction.

In this case the mass *M* of the rod is divided into two unequal parts, one of which M_w is concentrated at *W* and the other M_h at *H*, the relation between the points *W*, *G* and *H* being $\overline{GW} \times \overline{GH} = k^2$, where *k* is the principal polar radius of gyration. The two masses must be to each other as

$$M_w : M_h = \overline{GH} : \overline{GW}$$

Construct as before the acceleration *Ow* of the slide and *Cw* the image of the rod. At *G* erect the perpendicular $GE = k$. Join *E* with *W* and draw *EH* at right angles to *EW*. This will evidently satisfy the condition $\overline{GW} \times \overline{GH} = k^2$.

Through *H* and *G* draw *Hh* and *Gg* parallel to the stroke, then will the vectors *Oh* and *Og* represent in direction and intensity the accelerations of points *H* and *G*, respectively.

Through H draw HI parallel to Oh; it will cut at I the direction WI of the acceleration of the other mass at W. Through I draw, parallel to Og, the line IK; it will be the actual location of the resultant force of inertia of the rod, and its intensity = whole mass of rod × acceleration Og of centre of gravity.

These two constructions give, of course, exactly the same result, the first being a little the easiest when the intersection V falls within the limits of the paper. The great advantage of the second is that the direction of W is given by the line of stroke, and that the intersection I will always fall within the limits of the drawing. Both constructions of the total force of inertia fail at the dead point, but this is of no consequence, because then the direction and location of the total acceleration of the rod is known, for it coincides with the stroke, and, as before, its intensity = the whole mass × acceleration Og of the centre of gravity.

This construction is only one of an infinite number of possible cases, each of which satisfies these three conditions:

$$(1)\quad M = M_1 + M_2$$

$$(2)\quad M_1 : M_2 = h_2 : h_1$$

$$(3)\quad h_1 h_2 = k^2$$

k = principal polar radius of gyration.

h_1 = distance from centre of gravity G of point H_1, at which mass M_1 is concentrated.

h_2 = distance from centre of gravity G of point H_2, at which mass M_2 is concentrated.

M = total mass of rod. The points H_1 and H_2 lie in one straight line with G, and on opposite sides of G. By transformation and combination, we get

$$M_1 h_1 = M_2 h_2, \qquad \text{and} \qquad M_1 h_1^2 + M_2 h_2^2 = M k^2$$

which shows that any concentration of mass satisfying the above three conditions will develop the same pressures on its supports, and store the same energy as the original distributed mass. It is evident that $h_1 = h_2$ is a particular case of the general one just given, and is illustrated in

Fig. 1. Neither of the points H_1, H_2 is necessarily located at wrist-pin centre W, or on centre line CW of rod.

B.

This is meant to be the most general case of slider crank, with respect to the mechanism itself, to its motion and to the distribution of the mass of the rod. The mechanism LCW is of the crossed slider-crank type in which the stroke of slide W does not pass through centre L of crank. The rotation of crank CL is not uniform as in the preceding cases, the acceleration of crank-pin C, taking (say) the direction and intensity CO, instead of CL as before.

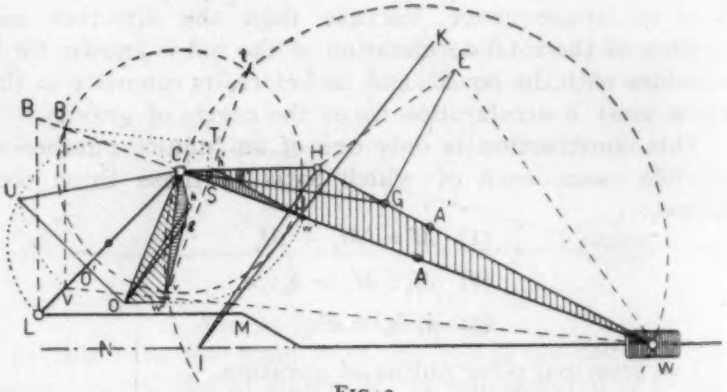

FIG. 3.

The centre of gravity of the mass is no longer in the centre line CW of the rod, but outside of it, at G. The point H is on the line WG as before, and again satisfies the condition $GW \times GH = k^2$, where k is the principal polar radius of gyration. H is found by the same construction, namely, we erect the perpendicular $GE = k$, join EW and draw EH at right angles to EW.

The velocity of the crank-pin is no longer represented by CL, as in *Figs. 1* and *2*, but by CV. It is found by construction, as follows: On crank CL as a diameter construct a circle LUC; from end O of acceleration draw a perpendicular $OO'U$ to CL; then will $CU = CV$ be the intensity of the velocity of the crank-pin C. To find the acceleration Ow of

slide, we proceed as in *Figs. 1* and *2*, except that a circle is described with CB' as a radius instead of CB.

In *Fig. 3* the distance OC and Ow, respectively, represent the accelerations of crank-pin C and wrist-pin W. The line Cw is the reduced image of the centre line CW of the rod. We may consider this rod to be an exaggerated specimen of the Westinghouse type in that its centre of gravity G is off the centre line CW of the rod. We may regard the triangle $CHGW$ as the representation of the rod and proceed to construct a reduced image of it on Cw as a base. To do this lay off $Cw' = Cw$, draw $w'h'$ parallel to WH and connect C with G. The triangle $Ch'g'w'$ is evidently similar to $CHGW$. Revolving it back to Cw as a base we get triangle $Chgw$ as the desired image of the rod, and Oh, Og will be, in direction and intensity, the accelerations of points H, G, respectively. Through H draw HI parallel to Oh; it will cut at I the direction WI of the acceleration of the other mass at W. Through I draw, parallel to Og, the line IK; it will be the actual location of the resultant force of inertia of the rod, and its intensity, as before, is equal to the product of the whole mass of rod $\times$ acceleration Og of the centre of gravity.

C.

An exact determination of the pressure exerted by rod against the crank- and wrist-pins must include its weight. We will, therefore, find the resultant of the weight and of the resistance due to inertia. As the inertia is measured by mass times acceleration, the expression of the force of inertia becomes:

$$\text{Inertia of rod} = \frac{W}{g} \times \frac{\overline{Og}}{\overline{OC}} \times \frac{v^2}{R} = F_2$$

W = weight of rod in pounds;
v = velocity of crank-pin in feet per second;
R = radius of crank in feet; and
g = acceleration due to gravity = 32·16 feet.

$\overline{Og}$ and $\overline{OC}$ = accelerations of centre of gravity and of crank-pin as given by *Figs. 1* and *2*. In the case of *Fig. 3*, we must substitute in the above expression for $\overline{OC}$ the value

$\overline{O'C}$. As the forces connected with engine are usually reduced to pressure per square inch of piston, the total inertia above given and the weight W should be divided by the area A.

In *Fig. 4* pass a vertical GQ through the centre of gravity G till it cuts the direction IK of the force of inertia of the rod. Make QS = weight of rod per square inch of piston, and QK = inertia of rod per square inch of piston. Complete the parallelogram; we get the diagonal PQR as the desired resultant of weight and inertia. This resultant must be overcome by the combined action of the pressures of crank- and wrist-pin.

Example: Harris-Corliss engine, $26\frac{1}{8} \times 60$· r.p.m. = 60. Length of rod = 150 inches. Weight of rod = 1,200

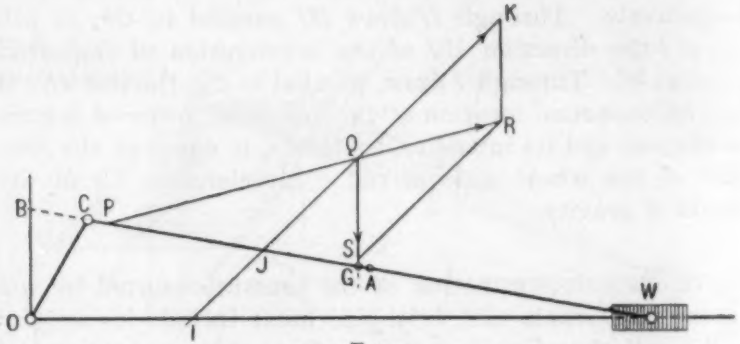

FIG. 4

pounds. Weight of other reciprocating parts = 1,300 pounds. Radius of crank = 2·5 feet. v = 15·71 feet per second. v^2 = 246·74. Principal polar radius of gyration = k = 48 inches. Distance of centre of gravity from wrist-pin = 78 inches. Distance of centre of oscillation from centre of gravity = 29·57. Assuming crank at 60° and drawing the mechanism to a scale of an inch to the foot, we get $\overline{Og}$ = 1·595 inches and $\overline{OC}$ = 2·5 inches. Substituting in the above formula and dividing by A, we have

$$\frac{F_2}{A} = 4{\cdot}38 = \overline{QK} \qquad \text{and} \qquad \frac{W}{A} = 2{\cdot}24 = \overline{QS}.$$

Exact computation * gives

$$\frac{F_3}{A} = 4{\cdot}37$$

which differs but 0·01 pounds per square inch from the result obtained by the graphical method. Considering the small scale, one-twelfth, employed, this shows the practical excellence of the graphical method.

In the above example the weight is about one-half of the inertia, but that is because the engine was large and of comparatively slow speed. In small, high-speed engines, the proportion is much less. Thus, in a *N. Y. S. S. P.* engine, 10 x 12, with rod of seventy pounds and 300 r.p.m. (*i. e.*, same crank-pin speed as in the large engine) we found

$$\frac{W}{A} = 0{\cdot}89 \qquad \text{and} \qquad \frac{F_3}{A} = 9{\cdot}21$$

or weight = one-tenth inertia. In the latter case the resultant will differ but little from the inertia in direction and intensity.

D.

When there is no friction at the pins, let P_c and P_w represent respectively the crank-pin and wrist-pin pressure. Let line *lq*, *Fig. 5*, represent the direction of the resultant of the weight and inertia of rod, and let the intensity of this resultant be assumed equal to $F_3 = lp = kh$. It is evident P_c and P_w combined must equal this resultant, and if one of these forces (say P_w) is known, the other P_c can be found by the parallelogram of forces. To obtain P_w we must satisfy two conditions, one of which is that P_w must do its part in producing the resultant F_3, acting along *lq*, and the other that P_w must balance the resultant of the guide reaction G and the driving force K of the piston. This force K is the

* The computation was made by the help of formulæ developed by Profs. Jacobus and Webb, in a paper published in *Trans. Am. Soc. Mech'l Eng.*, vol. xi. The data for the above example were obtained from this same source (see p. 498). The paper is analytical in character, but lays due stress on the practical questions involved; it is a valuable contribution to the subject of transmission of force in steam engines.

difference between the effective steam pressure P and the inertia F of piston, piston-rod and cross-head.

Through W draw Wz equal and parallel to F_3 ($= lp = kh$). Join any point l on lq with C and W. Draw zv and Wv, respectively, parallel to lC and lW. Through the intersection v draw vS parallel to centre line CW of rod, which line also represents direction of internal stress as C and W are the points of application of the forces. We will show later, that this parallel tS is the locus of the ends of all forces applied at W that satisfy the first condition mentioned above. Now lay off $Wb = K = P - F_1 =$ driving force and draw bt parallel to guide reaction G. The line bt is the locus of the ends

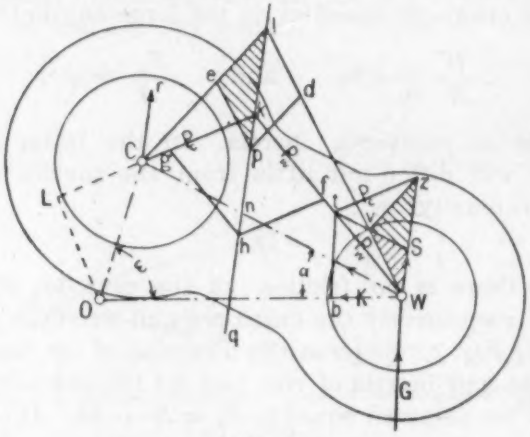

FIG. 5.

of all forces applied at W that satisfy the second condition. The intersection t of these two loci St and bt, gives $Wt = P_w$ the force desired. Prolong Wt to point k on line of resultant, then making $kh = F_3$ and $kf = Wt = P_w$ and completing the parallelogram, we get the crank-pin pressure $P_c = kg$ and the rotative effect $= P_c \times OL$.

For convenience of expression we will speak of the two components of each pin pressure as internal-stress-component and inertia-component. *The latter expression is not strictly correct as the second component not only overcomes the inertia but also sustains the weight of the rod,* but this will not at all affect the accuracy of our results.

Since the force P_c passes through crank-pin centre C, and may have its point of application anywhere on its line of direction without affecting its accelerating capacity, we will assume this point to be at C, and since force P_w passes through wrist-pin centre W, we will, for the same reason, take its point of application at W. This will make the centre line CW of the rod the direction of the internal stress caused by either P_c or P_w. Although the intensity of this internal stress varies as the inertia components of P_c and P_w are varied, nevertheless there is but one pair of forces P_c, P_w that will satisfy the conditions of this problem. To prove this it is only necessary to show that there is only one force P_w that will satisfy the conditions at the wrist-pin. One condition is that it shall be in equilibrium with the known force $K = P - F = Wb$ and the partly known reaction G of the guides. By drawing through b a parallel bt to the known direction of G, we get one locus for the end of the force P_w. Another condition that P_w must satisfy is, that it shall be the resultant of the internal stress acting along CW and the corresponding inertia component acting in any arbitrarily chosen direction. Let Wl be any such direction, then Cl will be the direction of the corresponding inertia component that acts at the crank-pin C. If $kh = lp = Wz = F_3$ is the known resultant of the weight and inertia of the rod, then $ld = Wv$ is the intensity of the inertia component acting along the assumed direction Wl, and $le = vz$ is the inertia component along Cl. Now draw through v a parallel Svt to the inner stress CW; it will divide the triangle Wvz into two triangles WSv and zvS, respectively, similar to triangles Wnl and lnC. Hence,

$$\overline{nW} \times \overline{SW} = \overline{vS} \times \overline{ln} = \overline{nC} \times \overline{Sz}$$

and

$$\frac{WS}{Sz} = \frac{nC}{nW} = \text{constant}$$

for this position and motion of the rod. Since Wz is also constant for this position of rod, the parallel Svt will pass through the same point S whatever the direction and intensity Wv of the inertia component. Therefore, the

intersection of *Svt* with the locus *bt* will give *Wt* as the only possible value of P_w for this position and motion of the rod.

Prolonging P_w to *k* and drawing *kC* and also *tz*, we get $P_c = kg = tz$. It is also evident from the figure that the reaction $G = bt$ of the guide is independent of the direction and intensity of the inertia component.

E.

When there is friction at the pins, let P_{cf} and P_{wf} represent, respectively, the crank-pin and wrist-pin pressures, and let *GKL*, *Fig. 6*, represent as before the location of the resultant F_3 of weight and inertia of rod. We will again suppose $F_3 = GN = KQ = PO = TL$ to be known. In this, as in the former case, P_{cf} and P_{wf} combined must be able to sustain the weight and overcome the inertia of the rod.

Moreover, P_{cf} must be tangent to a circle described from *C* as a centre with $\varphi\, r_c$ as a radius, and P_{wf} must be tangent to a similar circle about *W* with $\varphi\, r_w$ as a radius where φ is coëfficient of journal friction, and r_c, r_w, the radii, respectively, of crank-pin and wrist-pin. These circles are called friction circles, and have been in use for some time by writers on engineering. *No demonstrations concerning them need, therefore, be given here; we will simply say that each force is drawn on that side of the friction circle which will give a component opposed to the motion of the eye or pin according as the action of the pin or action of the eye is the force under consideration.

In *Fig. 6* the friction circles have been greatly exaggerated, and the rod given unusual proportions for the purpose of better illustration.

With this modification the force P_{wf} must satisfy the same two conditions as in the preceding case. But in that case it was known that P_w passed through the centre *W* of wrist-pin, and that point could, therefore, be assumed as its point of application. In the present case the possible values

*See Rankine's *Machinery and Millwork*, p. 428. Also Hermann-Smith's *Graphical Statics of Mechanism*, pp. 39–76.

of P_{wf} do not pass through such a common point, and we must, therefore, make use of trial methods to find P_{wf}.

We will first give a method which is, theoretically, the most exact, and then another, which is simpler, and, at the same time, accurate beyond the needs of practice.

From each of the series of points G, P, T on the line GL draw a tangent to each of the two friction circles *mnq* and *klp*. Make distances $GN = PQ = TL$ equal to the known force F_3 and resolve each of these distances into components

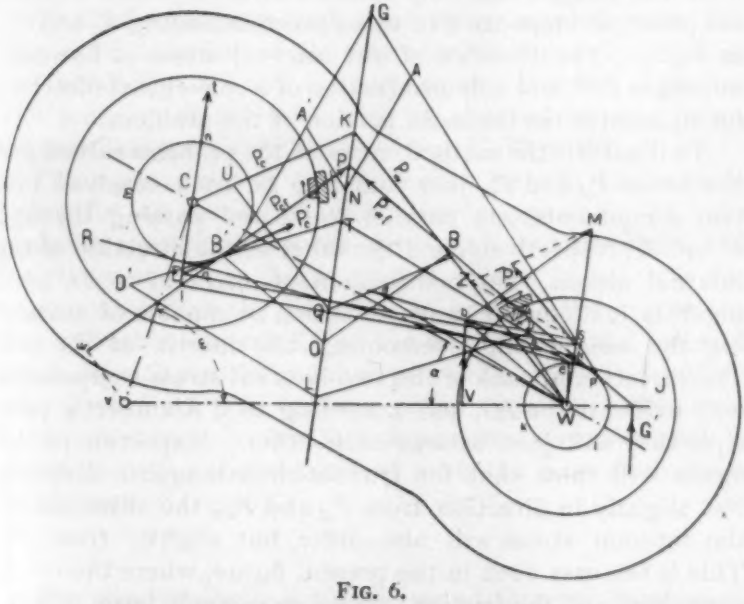

FIG. 6.

along the respective tangents. Then with W as a pole draw Wa equal and parallel to GA, Wb equal and parallel to PB, also Wd equal and parallel to TD, and so on, thus getting a polar curve *eabd*, whose vectors satisfy the condition that the pin forces shall be capable of balancing the resultant F_3. The second condition is the same in this as in the preceding case, namely, that the wrist-pin pressure P_{wf} shall be in equilibrium with the driving force $K = \overline{WV} = P - F_1$, and the given reaction G (known in direction only). Now, laying off $\overline{WV} = K$, drawing Vb parallel to the guide reac-

tion G', and joining its intersection b (with the polar curve *eabd*), to the pole W, we get in Wb the exact intensity and direction of the wrist-pin pressure P_{wf}, but not its location. The latter is found by drawing HBP parallel to Wb and tangent to the friction circle *plk*. Finally, drawing $PB'I$ tangent to friction circle *mnq* of pin C, and constructing the parallelogram of forces, we have $PB = Wb = P_{wf}$ and $PB' = P_{cf}$, the exact pin forces desired. The rotative force is measured by $P_{cf} \times \overline{vw}$.

In the simpler and only theoretically less exact method, the principal steps are like those taken in finding P_c and P_w in *Fig. 5*. The direction of the internal stress is, however, no longer CW, and a determination of a convenient direction for it, constitutes the main portion of the problem.

To illustrate the method, suppose the problem solved and the forces P_{cf} and P_{wf} just found to be each resolved into two components, one parallel to GL and passing through C and W, respectively, and the other in the direction of the internal stress. The two components parallel to GL must together just equal F_3 and, therefore, be capable of sustaining the weight and overcoming the inertia of the rod. The direction of each of the two internal stress components will evidently be HI, and according to d'Alembert's principle they will just balance each other. Inspection of the figure will show that for friction-circle-tangents differing but slightly in direction from P_{cf} and P_{wf}, the direction of the internal stress will also differ but slightly from HI. This is the case even in the present figure, where the rod is very short and the friction circles excessively large. Now, P_w differs but little, in direction from P_{wf}, and if we draw P_w' parallel to P_w and tangent to the friction circle *plk*, the location of this tangent will differ but little from the actual force P_{wf}. For the same reason P_c', parallel to P_c and tangent to *qmn*, will differ but little from P_{cf}. Joining the intersections F and E (of P_w' and P_c' with the parallel components WM and Ct, respectively), we get in FE a line whose direction is nearly parallel to the exact direction of the internal stress HI.

Our procedure in finding P_{wf} is, therefore, as follows: We

get the component WS as it was got in *Fig. 5*; we next draw through S a parallel Sb to the line FE, just described; then will Sb be a locus of the end b of the desired force Wb. But another locus is needed to completely determine b; this is given by the condition that $Wb = P_{wf}$ shall be the resultant of the driving force $K = P - F_1$, and guide reaction G'. Therefore, laying off $WV = K$ and drawing Vb parallel to G' we get a second locus whose intersection b with the first locus Sb gives the desired intensity Wb of the force P_{wf}, for Wb is common to each of the force triangles WSb and WVb, thus satisfying both conditions imposed upon P_{wf}. The exact location of P_{wf} may now be found by drawing pBP parallel to Wb and tangent to the friction circle plk. The accuracy of the work may be checked by completing the parallelogram $OBPB'$ and seeing if $PB = Wb$.

The approximation just given can be still further simplified for all cases that may arise in practice. In such cases the friction circles are very small and far apart, and the tangent RJ to both friction circles is scarcely distinguishable from the direction HI or EF. We may therefore treat this tangent RJ as the direction of the internal stress, draw Sb parallel and then proceed as above in the determination of Wb and location of its equal P_{wf}. The inaccuracy involved in this last approximate construction is much less than that connected with the best determined coëfficients of friction.

F.

The quadric chain $ABCD$ is one of interest because its derivatives are so extensively used in practice. We will now consider the special case in which one of the cranks (or levers), say AB, *Fig. 7*, has a uniform angular velocity. The velocity v, and acceleration $\frac{v^2}{R}$ of pin A may then each be represented by the length $AB = R$ of the crank. The direction AB of the acceleration of A, of course, coincides with the crank. If we suppose the direction of the velocity v of the pin A to be revolved through 90°, then in a certain sense the crank AB may be said to represent A's

velocity and its direction. The following beautiful and symmetrical construction of the acceleration of pin *D*, for this special case, was first given by Prof. T. Rittershaus, in *Der Civil Ingenieur*, 1880, p. 244, and in *Zeitschrift des Vereines deutscher Ingenieure*, pp. 287–289, 1883.

Prolong the opposite sides *AB*, *CD* and *AD*, *BC* to their intersections, the instantaneous centres *P* and *Q*. Through crank centre *B* draw *BJ* parallel to *CD* and *BI* parallel to *AD*. Join *J* with *P* and *I* with *Q*. Where *JP* cuts the parallel *BI* erect a perpendicular *OS* to *BI*, and where *IQ* cuts the parallel *BJ* erect the perpendicular *NS* to *BJ*. Then will *JS* represent in direction and intensity the acceleration of pin *D*, the common point of lever *CD* and of link or coupler

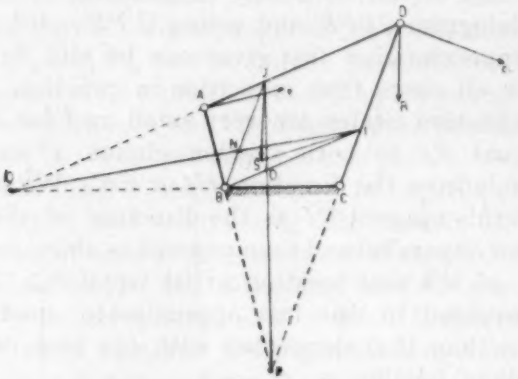

FIG. 7.

AD. Transferring *JS* to point *D* we have in *DR* the completely determined acceleration of point *D*.

If *AB* were the stationary link of the mechanism and *BC* the crank moving with constant angular velocity, *IS* would represent in direction and intensity the acceleration of point *D*.

[*To be continued.*]

CONFLAGRATIONS IN CITIES.

By C. J. H. Woodbury,
Vice-President Boston Manufacturers' Mutual Fire Insurance Company, Boston, Mass.

[*A lecture delivered before the Franklin Institute, Philadelphia, Jan. 23, 1891.*]

[*Concluded from p. 141.*]

There is scarcely a fire department which could not be feasibly reorganized by assigning one set of men to the care of apparatus, and another portion of the men—whose duty as hosemen and the like is to enter buildings at time of fire—to the inspection of buildings.

A measure of the benefit that might be derived from such work is shown in the reports of the underwriters' inspections in cities where such inspection service has been organized. The Inspection Department of the Boston Board of Fire Underwriters, organized June, 1884, and making about 11,000 inspections a year, has given very satisfactory results, indeed, particularly in regard to the improvement of property occupied by tenants, where the owners of buildings have been very much surprised at receiving information concerning dangerous conditions of which they had no knowledge, and have at once proceeded to correct the defects—the number of recorded improvements being 6,409 during the past year.

The results of the inspection at Boston have caused the organization of similar inspections in other cities, particularly at the West, where the work has been entered upon with much enterprise.

In Chicago the Inspection Department of the Fire Underwriters' Association makes about 16,500 inspections a year, disclosing 13,500 defects; and ninety-seven per cent. of these defects are reported as remedied. This department was organized in February, 1886, and great as has been the number of defects reported, the large proportion of corrections shows that the inspectors have not made requirements that were in the least degree impracticable.

In Philadelphia, the admirably organized Fire Underwriters' Association, which is broader in its scope than similar combinations in other cities, has had a corresponding increase in success, directly traceable to the efforts of its representatives.

The oldest inspection service, certainly in this country, is that at Moravian town of Salem, N. C., where a municipal fire inspection has been carried on for about 100 years, during which time there has not been an instance of a fire loss exceeding $1,000. Of course, the conditions there render large losses out of the question; but the adjoining new town of Winston, which has refused to adopt that method of inspection, has been subjected to numerous fire losses, although the physical conditions of the two communities cannot be far different from each other. My informant ascribes this difference in the fire loss to the municipal inspection at Salem.

The protective organizations, maintained in most large cities by the underwriters, have performed a vast deal of good work in the saving of property, but as stated in referring to the inspection corps, why should not such an organization, which is for the benefit of all, be directly sustained by the community as a public expense?

The methods of Factory Mutual Companies are often cited as proof of what can be done in reducing the fire loss; but the comparison is not exact in its application to methods which are feasible under conditions exposed to the conflagration hazard.

While it is absolutely true that these companies, or rather co-operations, have, for a series of over forty years, insured on a sound financial basis isolated industrial property devoted to the normally hazardous process of textile manufacture, paper making, and many varieties of metal working, at an annual cost in the vicinity of one-fifth of one per cent., or twenty cents on the $100—with the expectancy of a still lower cost in the immediate future, judging by the experience of recent years—yet it is questionable whether similar methods reaching identical results, are in any measure feasible for commercial risks in cities. It must be remem-

bered that these results are obtained from the peculiar conditions of a class of insurance.

The autonomy of these Mutual risks is well defined. Their isolation not only includes the absence of the conflagration hazard, but also a remoteness, or even entire absence of the services of an efficient public fire department, and therefore the policing of such property is most thorough.

The rules governing the operatives in the care of waste and dirt, the espionage of the watchman, whose patrol is recorded on a watchman's clock, the close supervision of the manager and his assistants, and in the generality of instances the methods of slow burning construction, isolating each room from the others without regard to architectural effects, the removal of unduly dangerous processes, as picking and dusting, from main buildings, the concentration of fire apparatus, pails kept filled with water, automatic sprinklers ready for instantaneous service, and numerous hydrants and hose at every point of advantage, furnished with powerful pumps and two independent sources of water supply, the apparatus manned by those who know every inch of the property protected; are all conditions which are entirely consistent with an insurance cost of one-fifth of one per cent.; and the wonder is that these precautions do not make the rate still less.

Such methods cannot be applied, except in part and in lesser degree, to commercial city risks; but every bit of experience goes to prove that they are of value in city risks to the measure that they are applied.

The great need is that of an awakened public sentiment, not merely in regard to a general knowledge of the causes of fire and the simple methods of their prevention, but also in regard to a general understanding of the fact that the cost of insurance is diminished with the adoption of every measure which tends to reduce the fire hazard.

FIRE-RESISTING CONSTRUCTION.

While the origin of most fires is due to causes which are in the control of owners or occupants, the destructive extent of nearly half of the fires is due to faulty methods of con-

struction, which might have been prevented in greater or less degree by the adoption of methods not involving excessive expense or unusual appearances in construction. These methods of safer construction are matters of common knowledge among competent architects, but they should not be held at fault for mistakes due to the avarice or prejudice of owners.

Methods of building construction, with a view to the application of methods of the greatest safety, need not interfere with the free exercise of the highest degree of taste. An ugly building is not necessarily a substantial one, any more than a homely person is necessarily good—although the greater portion of humanity willingly find comfort in the proverb concerning the Flemish beauty and the accompanying intrinsic merit.

The work of the underwriter is largely dependent on that of the architect, because every variety of building material and every method of construction, irrespective of the use to which the building is put, is more or less destructible by fire; therefore, the work of the architect must be judged, in a certain measure, by the methods of the underwriter.

There are certain types of construction of commercial and manufacturing buildings in cities, which experience has shown to be peculiarly adapted to resist destruction by fire, and a general consideration will be given to some of these methods.

If a building could be so constructed that its contents could burn and destroy the interior, without endangering the neighboring buildings, it could never cause a conflagration. A fire-proof building, however, is a commercial impossibility, because if one could be constructed so as to withstand the destruction of its contents, it would be good for little else, and the cost would be prohibitive.

When William A. Green was Chief of the Boston Fire Department, he received a letter from an official at Berlin, asking for a description of the fire-proof public buildings at Boston. He replied that they had but one, the Beacon Hill Reservoir, and sometimes they did not feel quite sure of that.

Improvements on the score of safety to buildings in cities are feasible only so far as they do not offend the present methods of taste in design, or interfere with the purposes for which such buildings are to be used; and all modifications must be made without undue cost, and under such conditions that any additional expense will prove a good investment in the diminution of the fire hazard, as measured by a reduction in the rates of insurance.

Any other method of treating the question in the attempt to direct the construction of buildings, regardless of all considerations except the reduction of the fire hazard, would be comparable to the answer of Brunel, the Civil Engineer, when he told the Parliamentary Commission that he believed the purpose of the Creator in making rivers was to feed canals.

The methods of safe and solid construction are, however, less expensive than the hollowness of alleged decorations, whose only definite characteristic consists in their perfect fitness as fire traps.

These questions of safe construction naturally resolve into two classes, the one including measures to prevent fires communicating from one building to another, and the other including measures to obstruct a fire from extending throughout the various stories of a building.

Both of these conditions may be idealities as to their complete fulfilment, but it has been found feasible to reach favorable results in these directions.

Any building ordinances which pertain solely to the entire construction of new buildings will be very slow in their application; but in most instances, changes can readily be introduced which would materially diminish both classes of hazard. Any measures which could do away with the conflagration hazard in cities would reduce the fire loss very materially.

The first consideration should be given to the means of reducing the conflagration hazard. This is accomplished simply by the maintenance of the walls, the protection of all necessary openings, the abolition of wood cornices, and the protection of the roof, all of which precautions have been taken in most of the first-class buildings in cities.

Brick division walls, heavy enough to withstand the excessive stresses incident to a fire, will be uninjured by flames which cripple iron and decrepitate stone. It is preferable that all walls should extend above the roofs; but where that cannot be done the cornices should be of terra-cotta, stone, or metal.

All openings in side or rear walls which would become a source of danger in case the adjacent buildings were on fire, should be provided with fire-proof doors or shutters, which should always be closed at night.

These doors or shutters should be made of two thicknesses of matched boards, of thoroughly seasoned stock, laid at right angles to each other and covered with sheets of tinned iron laid with locked joints similar to the method generally used in tin roofing. The hangings, whether trucks or hinges, should be secured directly to the wall, and fastened to the door or shutter by carriage bolts, not screws.

The butts for outside shutters should be made of galvanized iron, or some other material which would not allow the hinge to stick by rust. In division walls of large buildings these doors should be double, one door at each side of the wall.

Doors made after such a method have resisted the most severe exposure in burning buildings; while it is known that either wrought or cast-iron doors cannot withstand the heat of any considerable fire.

The occupant of a large building in Boston asked advice upon the best methods to render the building safer, and among other matters, it was suggested that tinned fire-doors should be placed at the openings in the division walls in place of the iron doors.

He replied that he would most gladly make the change, were it not that the conditions of the lease made it necessary that iron doors shall be kept at these openings. But, on being asked if any clause of the lease forbade the addition of tinned fire-doors in front of the iron doors, he replied in the negative, and afterwards had some excellent fire-doors made. They were, however, hung on hinges secured to the *furring* and *not* to the brick wall.

In a short time a fire started in the building, and, passing up the hollow spaces between the studding and the wall, caused the whole finish to separate from the wall, carrying the fire-door to the cellar, where it lay among some burning anthracite coal for a week, and was then removed to a certain insurance office, where it served as an excellent example for many years.

The iron fire-proof door, did not long remain in position after the tinned door was pulled away from in front of it, but yielded and allowed the fire to proceed through the opening into the adjoining building.

The floor supports should be attached to the walls in such a way that the walls shall not be injured by falling beams or girders. The preferable means for accomplishing this result is first to place the beams so they will not penetrate too near to the outer face of the wall. They should then be secured to the walls by a wall-plate with a tongue entering a transverse groove across the under side of the beam, or by the cast-iron anchorage box invented by Henry A. Goetz, the well-known architect. Wood beams anchored to the walls by either of these two methods will not endanger the walls in the event of a beam falling from any cause.

In the case of iron girders the problem is different, as the changes in the length of such girders with ordinary variations in temperature would not permit a rigid anchorage. This expansion has been sufficient in case of fire to produce serious results.

In his report on the great fire of November 28, 1889, the Boston Fire Marshal states, in regard to the Ames Building, which was among those destroyed, that the walls of the building were thrown out by the expansion of the iron roof. (*Boston City Document*, No. 17, 1890, p. 8.) Allegations have also been made concerning destructive results caused by the expansion of iron girders at other fires.

The question of roofs is a very important one, both in regard to their yielding from a fire inside, and also their ignition from outside exposure. The statement made by Benjamin Franklin, that "next to a good foundation, a good roof is the most important part of a house," is even more

applicable to-day, as the crowded condition of cities has given other functions to roofs than merely those of shelter.

The most substantial roofs for commercial buildings are those constructed of plank, and nearly flat, having a slope of half an inch to the foot either towards the centre or the edges. When the various courses of roof-covering comprise a solid thickness of three inches of wood without any intervening air-space, then the building is covered with a roof which will protect the upper story against extremes of temperature, resisting both the heat of summer and the cold of winter. A fire of the contents would not burn through such a roof so long as the supports were intact; and if the outside was protected by any roof-coverings suitable for flat roofs, it would be difficult for a neighboring fire to inflict any injury on such a roof. It is important that such a roof should have an opening covered with a door as thick as the roof, and that it should be provided with a permanent ladder or stairway leading to it.

The questions relative to the protection of buildings against fires originating in them, involve matters of detail pertaining to methods of interior construction and occupation which in themselves would exceed the limits of my allotted time; but at the risk of making some digressions not strictly bearing upon conflagrations, except in that relation which one fire always bears to another, the importance of the subject is offered as an excuse for referring to some of the salient features of interior defence against fire.

President F. C. Moore, of the Continental Insurance Company, states in his monograph on *Economical Fire Resisting Construction*, p. 4, that of the fires which exceed $100 in damage, only one-fifth are extinguished short of total destruction of the building and its contents.

In connection with this, it may be interesting to note the percentage of fires which caused a partial loss amounting to over $100 as compared with those which resulted in the general destruction of the building and contents, as shown in the reports of fires on property insured by the Boston Manufacturers' Mutual Fire Insurance Company, from which it is learned that in the last thirteen years there have been

457 fires, causing a damage of $100 or over, and only sixty-one of these fires may be classed as total losses, having caused the general destruction of the building and contents.

The greater proportion of the fires noted as total losses were in mill tenements, store-houses and dye-houses—classes of property whose conditions do not permit the application of methods of protection in general use in mills.

These facts in regard to fires occurring upon manufacturing property of normally great hazard, serve to show what results have been obtained by suitable precautions in the way of construction, fire apparatus and care.

It is not easy to introduce changes in the hazard of dwellings, as their owners and occupants are not inclined to vary from customary methods, but the owners of mercantile and manufacturing property are far more ready to give consideration to suggestions designed to reduce the fire risk.

A building made of incombustible material is not necessarily fire-resisting, as a combustion of the contents of almost all commercial buildings, except office buildings, will weaken unprotected iron beams and columns, and reduce the strongest stone to powder. This destruction of rock is caused by the conversion into steam of the water absorbed by the stone.

Nearly every city is provided with building regulations, which are generally teeming with errors of omission, and often contain provisions for methods of construction which are as far behind the times as the old buildings which are torn down to make way for the new structures to be erected in accordance with the provisions of the new regulations.

The increasing height of buildings, whose profitable use has been made possible by the passenger elevator—which was very properly designated by its inventor, Otis Tufts, in his patent as the vertical railway—presents a problem which is not fully met by the use of incombustible material in construction.

This increase in the height of buildings was clearly indicated a short time ago by one of the magazines (*Harper's*

Magazine, November, 1882), which contained two views of the Southern part of New York City—the one being from a daguerrotype of many years ago, and the other from a recent photograph taken from the same place in Brooklyn. Trinity steeple and a few landmarks served as scales by which to estimate the increasing height of buildings, which appeared to average certainly more than double—with exceptional examples lofty enough to suggest the sin of Babel.

Want of care in the construction of flues or chimneys is the cause of an enormous number of fires, especially from cracks caused in many instances by girders or beams too near chimneys. Soot deposited in such cracks becomes ignited in the course of time, and acts as a fuse to ignite some of the wood-work at the floors, or the interior finish of the building.

Hollow concealed spaces in floors and walls are a source of great destruction by fire. It is certainly preferable, as regards matters of safety, to design buildings without such dangerous spaces; but the traditions of construction seem to be so entirely opposed to such methods that they must be recognized, and faulty practice modified as far as possible by the introduction of fire stops in all vertical concealed spaces at each story, and any continuous spaces, particularly in the attic, should be cut off at as frequent intervals as can be arranged.

The ceilings over furnaces, boilers, and hotel cooking apparatus, if near enough to become in any manner a source of danger, require special provisions to insure safety. All hollow spaces should be removed, and wood-work is generally best protected by means of lime plaster laid on wire lathing, conforming to the surface of the under side of the floor.

The supports of a building should be arranged to resist injury as a result of the combustion of the contents, or of the lighter portion of the interior. Timber beams and columns fulfil this purpose as well as any material; but it is frequently necessary to use iron or steel to obtain the necessary strength, in which case the metal should be protected

with heat-resisting material, generally with special tiles made for the purpose.

The best type of a commercial building is that in which the floors are continuous; the openings for elevators, stairs, and transmission of power, being an enclosed tower. This isolation of the various rooms from each other would render such a building well nigh indestructible by fire, but such a separation would not generally be considered adapted to commercial buildings, with the exception of store-houses. During the last year I designed a six-story building of this description, which is situated in the compact portion of a city, and occupied by numerous tenants engaged in various kinds of manufacturing.

The floors of this building are of the usual slow-burning construction type, the timbers consisting of southern pine beams of eighteen feet span, bolted in pairs, making solid beams 12 x 14 inches, and laid eight feet on centres.

The floors upon these beams consist of three-inch spruce plank planed underneath and with splined edges. These planks are sixteen feet in length, and therefore, each one rests on three beams. In order to render the load on the beams uniform, the courses are broken every two feet. Two thicknesses of asbestos paper are laid on the plank before the top flooring of birch is laid.

The roof is similar in construction, but only three inches thick. It is lowest in the middle, and the brick walls form a parapet around the sides. All windows, except those at the front, are provided with tinned shutters.

The peculiar feature of the building, however, is the means used to isolate the various stories from each other by making the floors entirely continuous and without any openings whatsoever.

A tower in the middle of the building, placed 24 feet from the entrance, and measuring 10 x 17 feet, made of brick in the lower portion and 3-inch plank above, extends through the roof and is covered by a large skylight protected, as all skylights should be, by wire netting underneath.

This tower contains stairways and elevator; and at the rear is another division for the wash-rooms, and to carry

steam- and water-pipes. Adjoining this is the belt tower, the power being transmitted to each room along a line of shafting. The whole arrangement occupies an area 10 x 31 feet in the middle of the building, where the light is the poorest, being therefore the space least valuable.

This method of interior construction, instead of being an added expense, cost about $3,500 less than the estimates for a similar structure with joisted floors of equal strength and rooms of the same height in the clear.

The rate of insurance is said to be the lowest ever given to a building under those conditions of occupancy, height and exposure to conflagration hazard.

Similar methods can be applied to other commercial buildings, but it is doubtful whether this method of arranging a stairway might not interfere with the requirements necessary in many commercial buildings, particularly those devoted to retail business, and buildings where elaborate decoration in interior finish is desired; although in buildings where such displays are necessary, the construction could be rendered more fire-resisting by the adoption of methods involving a higher expense than the ordinary methods.

The advantage of sound construction has never been more strongly illustrated than in Paris during the commune of 1871, when the mob sought to burn the city by the free use of kerosene, and only succeeded in burning the individual buildings which were set on fire, notwithstanding that there was no fire department to combat the fires. Photographs of streets taken after these fires show that the front walls of the burned buildings were still intact.

Fire Apparatus.—Experience has shown that the most effective measures against the fire hazard are those in the nature of precautions. The inception of fires should be guarded against by taking especial care of all matters tending to originate or spread fires; and, secondly, methods of construction which tend to prevent the spread of fire from one building to another, and also to retard the progress of a fire through the same building, should be used.

Before referring to any forms of fire apparatus, consideration should be given to the service required of it, and that

is to stop combustion. In this connection I take the liberty of repeating the results of some computations which I recently used in an article elsewhere.

The burning of material is simply the rapid oxidation which takes place when such material is raised to its ignition point in the presence of a supply of oxygen; and the combustion can be stopped only by removing one of these two essential conditions.

The combustion of one pound of wood will produce 7,200 thermal units, and such combustion can be stopped by an amount of water which will absorb enough of the quantity of heat to reduce the temperature of the wood to below its ignition point, the smallest quantity of water being that which will be evaporated by the fire. To evaporate one pound of water at a temperature of 60° requires 1,119 thermal units; and, therefore, the amount of heat generated by the combustion of a pound of wood is sufficient to evaporate 6·43 pounds of water, and this is the minimum amount of water which will stop the combustion.

As a practical matter it requires the application of a much larger quantity of water to extinguish a fire. If the temperature of the water was increased 40° by the heat of a fire, 180 pounds of water would be required for every pound of burning wood. A fire in a cotton picker-room was successfully put out by automatic sprinklers fed by an elevated tank, and it was found that 107¾ pounds of water were used for each pound of cotton burned. The floors of all buildings, with the exception of dwellings, contain enough fuel in each floor to evaporate water to a depth of two to three feet upon the floor, without any reference to the combustible contents of the buildings.

In the great fire at Lynn, November 26, 1889, enough water was used to cover the burned area of forty acres to a depth of seven feet; and in the fire at Boston two days later, the amount of water used was sufficient to flood the area to a depth of 12 feet 7 inches.

Mr. Charles B. Brush, C.E., stated, in a paper read before the American Society of Civil Engineers (*Transactions*, vol.

xix, p. 110), that 100,000 to 150,000 gallons of water were used at the general average of dwelling-house fires.

The conclusion to be drawn from these facts coincides with the well-known result of experience, that a fire must be extinguished in its early stages or destructive results will ensue. The fire department should be summoned at once in case of fire, unless one is positively certain that the means at hand will surely extinguish the fire, and no chances should be taken, especially if the fire has penetrated any hollow spaces in the building. Few persons have a proper appreciation of the skill, the bravery and the ingenious appliances of city fire departments.

The importance of a public water supply was appreciated at Philadelphia at an early day, and great wisdom was shown in the pioneer work connected with the Fairmount water supply. But the increase in the height of the buildings, their greater area, and the peril of continuous exposures have largely increased the necessities of water supply in all cities above what would have been thought ample a generation ago.

The first fire engine in America was made by Joseph Jenks, at the Saugus Iron Works, in accordance with the vote passed at the Boston town-meeting, March 1, 1653, after a large fire, ordering that "The Select (men) have power and liberty to hereby agree with Joseph Jynks for Ingins to convey water in case of fire if they see cause so to do."

The use of private fire apparatus has, in good hands, given excellent results; but fire apparatus, like all other possessions, needs care—even fire pails must be kept full—and unless such fire apparatus receives proper care it is worse than none.

Automatic sprinklers have given the best results of any private apparatus next to fire pails. As to their efficiency for mercantile risks, Messrs. Anderson & Stanton, insurance agents of New York, who make a specialty of underwriting upon such protected property, state that from January 1, 1887, to January 1, 1891, they have written $19,169,105 on this class of buildings, receiving as premiums $215,840; and during this time they have suffered losses to the amount

of $7,689 in twenty-five fires which have occurred—this amount being about three and one-half per cent. of the premium.

These results are even better than those of another insurance company, underwriting for the most part on manufacturing property protected by automatic sprinklers, where the results of thirteen years' experience show that the average loss on fires starting under automatic sprinklers, where these devices formed a part of the apparatus in service, amounts to one-eighteenth the average loss on fires under other apparatus than automatic sprinklers.

An exaggerated opinion of the efficiency of automatic sprinklers should not be based upon these results, as there have been instances, and will be many others, where the water is shut off either by malice or accident; and under exposure to processes generating corrosive fumes automatic sprinklers will undoubtedly be disabled by corrosion, although there is a wide difference between the various types of sprinklers in this respect.

In answer to a request for the best method of protecting certain buildings in Boston which were exposed to an excessive conflagration hazard, roof hydrants were suggested by an officer of an insurance company that was not interested, because it did not write upon city risks. These hydrants were placed in accordance with the suggestion, and the great fire in that city, November 28, 1889, was stopped in one direction by water supplied, at the rate of 2,500 gallons per minute, by private fire pumps, and poured from these roof hydrants upon burning buildings which had fallen, burying men and apparatus, and blocking the street in such a way as to prevent the use of the city fire apparatus at these points.

Such roof hydrants are worthy of more general application in city risks, and if surmounted by monitor nozzles, which will remain in any position in which they are placed, they could continue to do good service even after the smoke and flames had driven persons away from the roof.

All of this private fire apparatus tends to economize the city water supply, because of the efficient manner in which

water can be applied by such means at the early stages of a fire.

The general tendency of the management of city water works has been against private fire apparatus, although the experience on this matter has been of an opposite nature. Such apparatus, however, should not be connected to a public water supply, except under the most careful regulations.

Conclusion.—The adoption of any of the protective measures presented in this paper will fall short of the desired results, unless the community in general throws off its apathy in regard to the fire loss, and with a thorough realization of the easily preventable nature of much of this great waste, becomes interested in creating a public sentiment that will make a demand for conditions of safety.

Insurance rates in the cities are double what they should be, although they do not give a sufficiently remunerative income upon the capital invested in insurance, because the fire losses are so much greater than what they should be.

Major George S. Merrill, Insurance Commissioner for Massachusetts, states, in his report for 1890:

"It is within bounds to say that ninety per cent. of all fires arise from causes absolutely within the power of the individual to prevent." (*Thirty-fifth Annual Report of the Insurance Commissioner of Mass.*, p. 20.)

The fire hazard of a city abounding in humanity, and with a concentration of property, is a contingency terrible to contemplate, and would indeed be far more terrible in its realization were it not for the wonderful skill and bravery of fire departments in coping against the unequal odds of continuous combustibility.

This question is one of the greatest problems of municipal government, and does not its true solution lie in strengthening the hands of the administration of the fire departments by also giving them ample power in the matter of preventing fires by assigning to them inspection duties, such as have already proved to be so valuable in the hands of insurance organization, and would no doubt be even more efficient in the hands of persons acting under suitable authority of the law?

The same reasons apply to the organization of protective departments, which are now for the benefit of all sufferers by fire, but like the inspection corps maintained by private organization.

It will be for others to say how far individual rights under the law may prevent compulsory changes in existing buildings; but the building laws which are needed in cities are those which would apply to existing buildings rather than those regulating the construction of new buildings.

The whole question of the reduction of the conflagration hazard is one of possibilities, and this hazard can be reduced by general action on the part of any municipality to any extent that is demanded by general public opinion.

NEW ALLOYS AND THEIR ENGINEERING APPLICATIONS.

BY F. LYNWOOD GARRISON.

[*A lecture delivered before the Franklin Institute, January 30, 1890, and February 6, 1891.*]

[*Concluded from p. 129.*]

"The enormous elongations reported may give a greatly exaggerated notion of the metal's ductility. A test bar of iron or carbon steel undergoes a certain amount of elongation over its whole length, but much of its elongation occurs just at and near the point of rupture, where the metal 'necks.' It is owing to this that the percentage of elongation of short iron test bars is so much greater than that of long ones. Manganese steel, however, like brass, stretches more nearly uniformly over its entire length, without much necking. Its elongation would exceed that of equally strong carbon steel, much less if measured over a length of one-eighth of an inch, than if, as now, measured over eight inches. Now, elongation is indeed an index of toughness and ductility; but the relative toughness of different metals, under given conditions, can be safely inferred from their elongations only when these elongations occur in like man-

ner. For certain conditions it may be better, for others worse, that the elongation should be distributed as in manganese steel, rather than concentrated, as in carbon steel. But, while we may dispute whether the toughness of manganese steel of twenty-five per cent. elongation is, on the whole, greater or better, rather than worse than that of carbon steel of like elongation, the important point remains that it has a different toughness, which does not necessarily fit the metal for the purposes to which carbon steel of twenty-five per cent. elongation is properly put." "Thus, Stromeyer found that manganese steel, whose elongation under tensile stress led him to expect that it could be bent back and forth many more times before rupture than wrought iron, and carbon steel was actually rather more brittle when tested in this way, enduring only seven bendings when in its natural state, and from ten to eighteen after quenching from redness, while wrought iron and carbon steel endured in four cases 20, 26, 12·5 and 21 bends."

"Again, the results in Table IV show that, while the shock-resisting power of manganese steel of 12·55 per cent. of manganese is much greater than that of the best carbon axle steel with which it was compared, yet in spite of its enormous elongation under static tensile stress, its ultimate deflection on rupture, under transverse shock, is less than half as great as that of carbon steel."

EFFECT OF TRANSVERSING SHOCK ON MANGANESE AND CARBON STEEL. *Hadfield.*

	Energy Developed in Foot Tons.	Sum of Permanent Deflections. Inches.	
		Special Carbon Steel Axle.	Manganese Steel Axle.
At the 5th blow, ...	79·883	24·953	8·501
" 10th "	208·531	66·188	19·403
" 15th "	348·591	105·248 broke.	30·212
" 20th "	497·988	—	39·491 broke.

Bars 4½" in diameter and 4' 6" long, on bearings 3' apart, were struck by a 20·75 cwt. ram, and reversed after each blow.

Manganese steel is usually made by adding ferro-manganese to molten Bessemer or open-hearth steel in a ladle.

MANGANESE AND SILICO-MANGANESE STEEL SHOWN AT PARIS BY HOLTZER. *Howe.*

Number.	Per Cent. of Manganese.	Tensile Strength. Pounds per Sq. In.			Elastic Limit. Pounds per Square Inch.			Elongation. Per Cent. in 7·9 Inches.			Contraction of Area. Per Cent.		
		Natural State (forged).	Oil-hardened and Tempered	Oil-hardened and Annealed.	Natural State (forged).	Oil-hardened and Tempered	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Tempered	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Tempered	Oil-hardened and Annealed.
1	·20@·30	83,488	146,210	112,075	42,668	109,230	91,026	22	12·5	13	42	45	38
2	—	87,612	149,197	131,134	49,210	110,227	98,706	14	11·8	10	—	46	46
3	—	97,710	154,175	161,571	46,366	119,736	129,285	20·8	8·5	13	42	36·5	40
4	—	107,382	163,277	141,232	57,033	133,402	122,600	16	10	11·8	35·5	41	43·5
5	—	102,546	175,651	154,175	57,033	146,210	133,409	19	7·5	8·5	51	31	45
6	10 ±	98,706	176,363	148,201	55,042	155,882	121,605	23·5	8	11·5	42·2	31	40
7	12@14	115,631	122,316	137,107	58,882	61,869	52,908	29	28	41·5	26	28·3	36·5
8	—	51,202	87,328	68,553	38,970	63,575	52,197	36	15	24·5	73	76	72·5
9	—	96,572	139,098	128,289	47,219	19,200	100,555	14	10·5	11·2	21	42·2	46
10	—	91,026	159,580	133,409	44,517	118,763	104,538	21·5	13	10·5	42·2	38·5	46
11	2 ±	98,021	161,571	146,210	47,504	139,098	121,605	23	10	12·5	50·5	38·5	46

The "natural state" pieces are simply cooled slowly after forging.
The oil-hardened and tempered pieces are quenched in oil from about W, a low yellow and slightly reheated.
The oil-hardened and annealed pieces are similarly quenched, then reheated to very dull redness, say V, and cooled slowly.

It is less desirable to mix them in crucibles on account of the strong corroding action of the manganiferous slag. The steel usually contains on analysis 0·5 per cent. less manganese than the amount added in the ferro-manganese.

The chemical reactions taking place in the manufacture of manganese in steel are probably very much the same as those taking place in the manufacture of manganese bronze. The dissolved oxide of iron present in the steel is deoxidized by the manganese in the same way as the dissolved cupreous oxide present in the metallic copper is deoxidized in making manganese bronze. The dissolved oxide of iron is promptly reduced by the manganese, forming a double silicate of iron and manganese, which readily slags off.

In the Bessemer and open-hearth processes of making steel, the metal under ordinary conditions becomes somewhat oxidized. Manganese is then usually added at the completion of these processes in the form of a manganiferous cast iron (spiegeleisen or ferro-manganese). This reduces the iron oxide, and in turn is itself oxidized and scorified.

Again, the presence of manganese in solidified steel appears to hinder its oxidation in heating and forging. The reaction of forming a double silicate of manganese and iron in molten steel seems to perform another function. It appears that molten steel usually contains minute mechanically suspended particles of slag, which cause "red-shortness." This suspended slag unites with the silicate so formed, rises to the surface and is fluxed off. The presence of manganese is very useful in steel by counteracting the red-shortness caused by the presence of sulphur, and in some cases it actually removes this metalloid from iron, sometimes (probably because sulphide of manganese like sulphide of calcium is less soluble in metallic iron than is sulphide of iron) by forming some compound rich in sulphur and manganese which liquates off, and perhaps carrying oxygen to the sulphur.*

* Howe's *Metallurgy of Steel*, p. 43.

The extreme point of brittleness of manganese steel occurs in the material containing from four to five per cent.; above this a slight increase in strength takes place; but even at about six and one-half per cent. it will only stand the same transverse test as cast iron.

Another singular point is that the carbon in such brittle samples is not over 0·3 to 0·5 per cent. or very little more than in mild steel. In fact, it has been noticed that the more purely the alloy consists of iron and manganese, the more brittle the product. According to Hadfield,* a piece of manganese steel heated sufficiently to be seen red hot in a dark place, on being plunged into cold water becomes soft enough to be easily filed, planed or otherwise fitted. Hardness is then restored by reheating to a bright red, and cooling in air. This kind of steel is especially useful for cutters for boring out bosses of wheels.

The maximum amount of manganese that may be present in low grades manganese steel before the steel becomes absolutely brittle, seems to be about two and one-half per cent.† The peculiar brittleness and extreme hardness begins to disappear at about seven and one-half per cent. manganese. Cast car wheels of manganese steel will usually outwear four or five ordinary ones.

Extremes of atmospheric heat and cold do not appear to affect the properties of the best grades of manganese steel.

When manganese steel contains from seven to twenty per cent. manganese, especial care must be taken not to overheat the ingots, or they will "burst" when under the hammer. This grade usually works well, is hard and close, rolls well, can be sheared when red hot; but does not weld properly.

In analyzing manganese steel no trace of graphite has been found, all the carbon present being in the combined form.

The ordinary crucible steel process is not only unsuitable for making manganese steel, on account of the manganese

* *Proceedings of the Institute of Civil Engineers*, vol. xciii.

† R. A. Hadfield, in *Proceedings of the Institute of Civil Engineers*, vol. xciii.

slagging and cutting out the pots, but, on account of more or less carbon being taken up from the graphite in them. Manganese steel seems to be especially useful for car-wheels, on account of its combined hardness and toughness; and bed-plates of dynamos owing to its low magnetic susceptibility.

It has not been found serviceable for armor plate, probably owing to its relative low crushing strength in resisting penetration by projectiles, its extreme hardness in resisting abrasion must not mislead us in this respect.

At present its use is very much restricted by the extreme difficulty in its machining and forging. These difficulties and its liability to crack in quenching led some of the large steel works in France to wholly abandon any serious attempts to use it for armor plate.*

Its combination of great ductility and tensile strength should give it many important uses, while its remarkable combination of ductility and certain kinds of hardness is unsurpassed.

The alloy has been applied to the manufacture of tools with very good results. It is simply necessary to cast the metal into shapes, and grind it.

Couplers of the vertical plane type have also been cast of it, and the inventor (Mr. R. H. Hadfield, of Sheffield,) gives extremely interesting tests of the amount of work required to bend one of these couplers when subjected to the same kind of shock which they would receive in coupling cars. The best sample coupler contained 14·50 per cent. manganese, had been water-toughened, and stood a total energy of 320·87 foot-tons, with a total set in jaw of 0·65 inch, and was still unbroken. An American malleable iron coupler, tested in same way, was subjected to total work of 43·37 foot-tons, with a total set of 0·90 inch, and was broken.†

The exceptional hardness of manganese steel, together with its great ductility and strength, make it unsurpassed for the manufacture of steel tires and axles. Its applica-

* Howe's *Metallurgy of Steel*, p. 365.

† *Report of Science and Arts Committee of Franklin Inst.*, Nov. 18, 1890.

tion in the arts would doubtless be much more extensive were it not for its intense hardness; such difficulties, however, are mechanical, and it seems likely, in the course of time, they will be overcome in one way or another. When manganese steel can be made by the simple addition of metallic manganese and the simultaneous addition of iron and carbon, as is at present the case, avoided, we may expect even better results.*

Nickel Steel.—The subject of nickel and steel alloys was first brought to the attention of the engineering world by Mr. James Riley, of Glasgow, in a paper read by him before the British Iron and Steel Institute, at their meeting in May, 1889.† Quite recently the subject has acquired much greater notoriety, owing to the results of armor-plate tests lately made at Annapolis. In these tests nickel steel was shown to be superior to simple steel (carbon steel) and compound plates.

Apparently from no other conclusive investigations or tests than these, the United States Navy Department has decided to use nickel steel exclusively for armor plate. It seems to me the wisdom of this policy is very questionable and short-sighted, in view of some of the remarkable results which have been obtained with other and cheaper steel alloys.

In 1889 M. Henry Schneider, of Creusot, France, took out two patents for the manufacture of alloys of cast iron and nickel and steel and nickel, respectively.‡

In the specifications of the first patent, it is stated that it is very diffcult to incorporate nickel with iron and steel, particularly when it is attempted to produce these alloys on a commercial scale. "To overcome this difficulty, a preliminary product is made of cast iron and nickel in a crucible, cupola, or open-hearth furnace. This product or alloy, while specially useful for the manufacture of iron

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* The only difficulty in the way of using metallic manganese is its great cost.

† *Journal*, No. 1, 1889, p. 45.

‡ U. S. Patents 415,657 and 415,655, Nov. 19, 1889.

(*Garrison.*)

TENSILE TESTS OF NICKEL STEEL. *J. Riley.* (*a*)

Number.	Composition. Nickel.	Carbon.	Manganese.	Tensile Strength. Lbs. per Sq. In. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.	Elastic Limit. Pounds per Sq. In. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.	Elongation, % in 8 Inches. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.	Elongation, % in 4 Inches. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.	Contraction of Area, %. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.	
1	1·0	·42	·58	(*b*)	—	—	—	(*b*)	—	—	—	(*b*)	—	—	—	—	—	—	—	(*b*)	—	—	—	
				—	122,304	—	—	—	61,152	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
				—	—	129,024	—	—	—	71,904	—	—	—	—	—	—	1·5	—	—	—	9·5	—	—	
2	2·0	·90	·50	—	—	—	123,424	—	—	—	67,424	—	—	—	—	—	—	11·0	18·7	—	—	24·0	45·0	
				Unmachinable.																				
3	3·0	·35	·57	78,176	—	—	—	41,352	—	—	—	—	—	—	—	2·5	—	—	—	5·6	—	—	—	(*c*)
				—	78,176	—	—	—	53,760	—	—	—	—	—	—	—	2·5	—	—	—	9·0	—	—	
				—	—	114,740	—	—	—	70,336	—	—	—	—	—	—	—	20·3	—	—	—	37·0	—	
4	3·0	·60	·26	—	—	—	108,640	—	—	—	62,720	—	—	—	—	—	—	—	20·3	—	—	—	42·0	
				—	—	115,360	—	—	—	65,856	—	—	—	—	—	—	—	10·1	—	—	—	9·0	—	
5	4·0	·85	·50	—	—	—	96,960	—	—	—	67,872	—	—	9·0	7·5	—	—	—	9·0	—	—	—	12·0	
				Unmachinable.																				
6	4·7	·22	·23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
				—	—	90,720	—	—	—	56,224	—	—	—	17·75	—	—	—	23·4	—	—	—	42·0	—	
				—	—	—	90,944	—	—	—	62,720	—	—	—	20·0	—	—	—	25·0	—	—	—	44·8	
7	5·0	·30	·30	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
				—	—	103,936	—	—	—	67,200	—	—	—	10·0	—	—	—	12·5	—	—	—	22·5	—	(*d*)
				—	—	—	95,424	—	—	—	62,720	—	—	—	15·0	—	—	—	17·5	—	—	—	18·5	
8	5·0	·50	·34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
				—	—	116,480	—	—	—	69,664	—	—	—	14·0	—	—	—	15·6	—	—	—	14·0	—	
9	10·0	·50	·50	—	—	—	104,832	—	—	—	72,800	—	—	—	13·5	—	—	—	14·0	—	—	—	17·0	
				Unmachinable.																				
10	25·0	·27	·85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(*e*)
				—	—	115,136	—	—	—	85,568	—	—	—	10·5	—	—	—	11·7	—	—	—	—	—	
				—	—	—	102,592	—	—	—	28,560	—	—	—	29·0	—	—	—	30·0	—	—	—	28·6	
11	25·0	·82	·52	—	—	106,624	—	—	—	49,280	—	—	—	43·5	—	—	—	47·6	—	—	—	60·0	—	
				—	—	—	94,304	—	—	—	32,824	—	—	—	40·0	—	—	—	45·3	—	—	—	43·6	
12	49·4	·35	·57	—	—	83,776	—	—	—	45,920	—	—	—	—	—	—	—	12·0	—	—	—	24·0	—	
				—	—	—	82,880	—	—	—	47,040	—	—	—	—	—	—	—	20·0	—	—	—	29·0	
13	—	—	—	214,144				120,960				—				9·37				49·2				
14	—	—	—	219,834				116,502				7·8				—				52·4				
15	—	—	—	210,246				120,780				8·2				—				50·0				

(*a*) J. Riley, *Engineering*, May 17, 1889, p. 574, a paper read before the Iron and Steel Institute.
(*b*) Test-piece defective.
(*c*) Too hard to machine with Mushet's steel. Good tools may be made from it by quenching from dull redness in boiling water.
(*d*) The average is reduced by the low results given by one test-piece.
(*e*) Too hard to machine. Good cutting tools may be made from it by cooling in a blast of cold air.

and nickel and steel and nickel alloys, may be used as castings for a variety of purposes.

"In the manufacture of this alloy of cast-iron and nickel, a suitable furnace is charged with nickel scrap and ordinary cast or pig-iron, with carbonaceous matter; or the nickel may be in the form of nickelized compounds or coke. The operation is best carried on in a reverberatory furnace under a layer of anthracite, to avoid oxidation.

"The resulting alloy contains from five to thirty per cent. nickel, and is remarkable for its great elasticity and strength —properties which may be still further developed by chilling or tempering in the usual manner.

"This alloy of cast iron and nickel, containing (say) thirty per cent. of nickel, sixty-three per cent. of iron, three per cent. of carbon and two of manganese and silicon, is then charged on the bed of an open-hearth furnace, with the iron or scrap used in the ordinary methods of making open-hearth steel, care being taken to protect the bath from oxidation by means of a layer of slag or cinder. A steel, containing about five per cent. of nickel, is thereby obtained. Precautions, however, must always be taken to prevent red-shortness in the metal before the final introduction of the recarbonizing and manganiferous silico-spiegel iron or ferro-manganese.

"Nickel steel of this kind, containing five per cent. of nickel, is especially adapted or suitable for use in the construction of ordnance, armor plate, gun-barrels, projectiles and other articles employed for military or other like purposes, or the manufacture of commercial sheets, bars, etc.

"The percentages of carbon, silicon and manganese can be regulated according to the degree of hardness required, but in all cases, in order to obtain the best results possible, the product must invariably be tempered in an oil or other bath"*

What is known as "Marbeau's nickelo-spiegel" is made by a patented process, which consists in the reduction of the ores of nickel, iron and manganese at the same time and in

* U. S. Patent 415,655, Nov. 19, 1889.

one operation. The following proportions are stated as affording good results:*

Nickel ore or matt, containing ten per cent. of nickel, . .	2 tons
Manganese ore, containing ten per cent. manganese and forty per cent. iron, ...	1 ton
Iron ore, containing fifty per cent. iron, ...	12 cwt.

An alloy of nickel and iron having thus been obtained, there appears to be but little difficulty in working this nickel iron into a nickel steel by means of an open-hearth furnace.

Riley states the alloy (nickel steel) can be made in any good open-hearth furnace, working at a fairly good heat.† No special arrangements are required for casting, the ordinary ladles and moulds being sufficient. If the charge is properly worked, nearly all the nickel will be found in the steel—almost none is lost in the slag.

No extraordinary care is required when reheating the ingots for hammering or rolling. If the steel has been properly made, and is of correct composition, it will hammer and roll well, whether it contains little or much nickel. Riley‡ appears to have obtained the best results with steel containing five per cent. nickel. With this grade rolled, but not annealed, he obtained elastic limit 69,664 pounds per square inch, tensile strength 116,480 pounds per square inch, with fourteen per cent. elongation in eight inches. When rolled and annealed, elastic limit 72,800 pounds per square inch, tensile strength 104,832 pounds per square inch with thirteen and one-half per cent. elongation in eight inches.

Riley states that the whole series of nickel steels up to fifty per cent. nickel takes a good polish and finish. Steels rich in nickel are practically non-corrodible, and those poor in nickel are much better than other steels in this respect.

The alloys up to five per cent. of nickel can be machined

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* *Engineering and Mining Journal*, Jan. 31, 1891. See U. S. Patent 419,274; also British Patents 2,573 of 1884, and 7,179 of 1885.

† *Journal of the Iron and Steel Institute*, No. 1, 1889, p. 45. *Journal of the Franklin Institute*, May, 1890, p. 367.

‡ *Ibid.*, p. 48.

with moderate ease, beyond that they are more difficult to machine.

The one per cent. nickel steel welds fairly well, but this quality deteriorates with each addition of nickel.*

J. F. Hall, of Sheffield, states that he has made nickel steel with as much as ninety-seven tons per square inch (217,280 pounds) tensile strength, and over seven per cent. elongation.†

Mr. G. J. Snelus states that one of the remarkable peculiarities of nickel steel was that the extension of some of the specimens appeared to be uniform over the whole length. This is probably accounted for by the fact that nickel is closely allied in its nature to iron.‡

Alloys of iron and other metals are very apt to be unsound and the test pieces usually give way at their weakest points; frequently the rupture takes place locally, and the extension only over a particular area.

The tests of some of the nickel steel recently made by Carnegie, Phipps & Co., Pittsburgh, for the U. S. Navy Department, gave the following results: elastic limit (two specimens) 59,000 and 60,000 pounds per square inch, ultimate tensile strength 100,000 and 102,000 pounds per square inch, elongation fifteen and one-half per cent., and reduction of area at fracture twenty-nine and one-half and twenty-six and one-half per cent. The test pieces were cut from three-fourths-inch plate. The chemical analysis gave a content of three-sixteenths per cent. nickel.§

Howe states‖ that the hardness of nickel steel depends on the proportion of nickel and carbon jointly, nickel up to a certain percentage increasing the hardness, beyond this lessening it. Thus white steel, with two per cent. of nickel and 0·90 per cent. of carbon cannot be machined. With less than five per cent. nickel it can be worked cold readily, provided the proportion of carbon be low. As the propor-

* *Journal of the Iron and Steel Institute*, No. 1, 1889, p. 52.
† *Ibid.*, p. 58.
‡ *Ibid.*, p. 59.
§ *Engineering and Mining Journal*, Dec. 13, 1890.
‖ *Metallurgy of Steel*, pp. 370, 371.

tion of nickel rises higher, cold-working becomes less easy. According to Howe, it forges easily whether it contain much or little nickel.

The presence of manganese in nickel steel is most important, as it appears that without the aid of manganese in proper proportions, the conditions of treatment would not be successful.

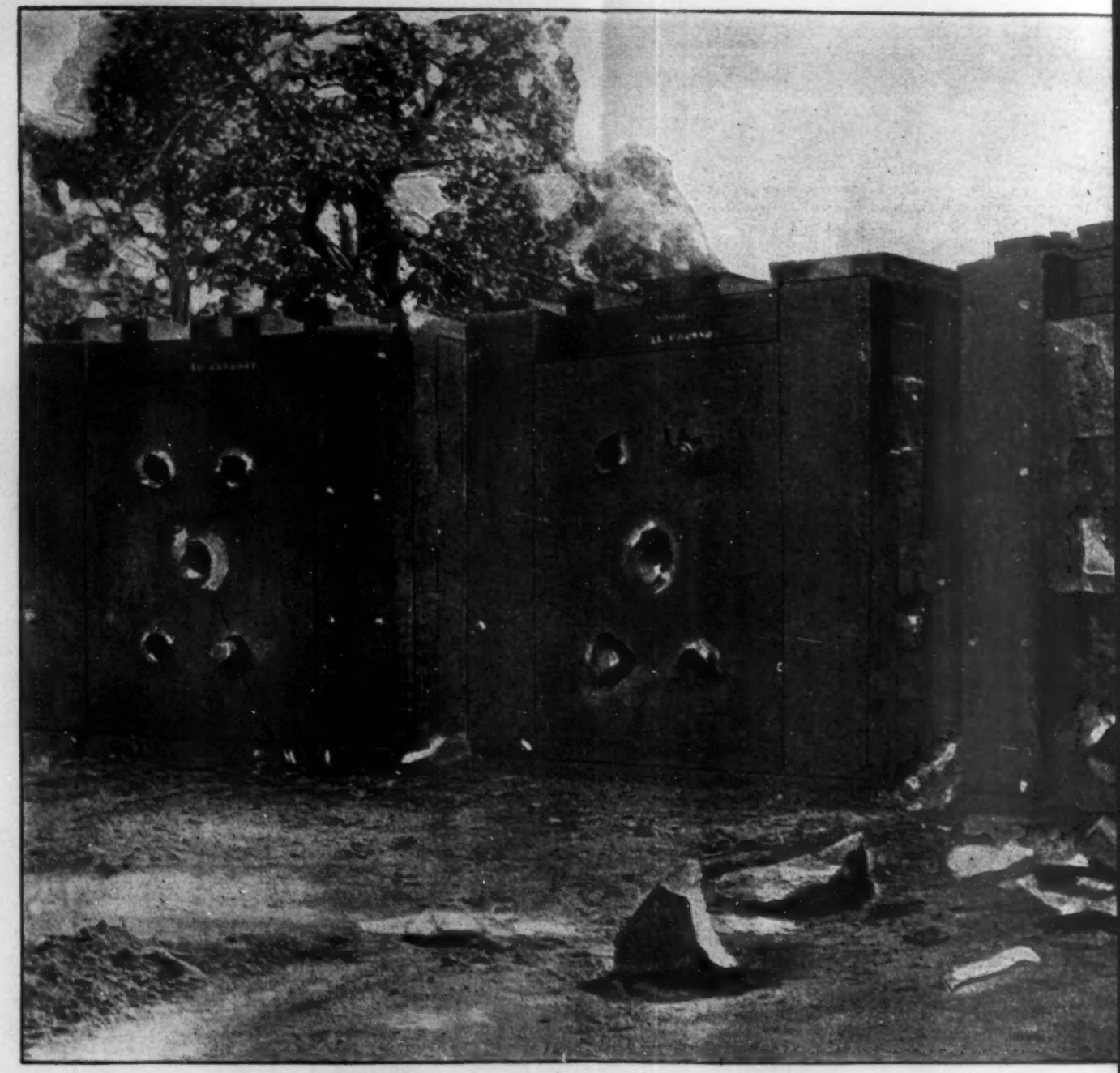
Nickel steel does not seem to be nearly so liable to corrosion in salt water as the ordinary and purer grades of steel. It might be observed in this connection that the corrosive action of salt water is much greater on ordinary steel than on the more impure qualities of iron.

Nickel steel would, therefore, seem to be a great advance, as it appears to combine the splendid qualities of mild steel for structural purposes with a greater limit of elasticity and less corrodibility than either ordinary steel or iron.

Ship owners obtained, by the use of mild steel in the construction of ships, an advantage represented by a saving of twenty-five per cent. of fuel. Now if nickel steel will give a material of (say) thirty per cent. more strength, this reduction of fuel will be yet further increased.

Electrical Properties.—The conductivity of nickel steel is extremely poor and low, but the resistance very high. According to Hopkinson, nickel steel, containing less than five per cent. nickel, is decidedly more magnetizable than wrought iron, particularly for high inductions. On the other hand, when containing twenty-five per cent. nickel, it is non-magnetic. But if cooled to —20° C. (—4° F.), it becomes very decidedly magnetic and remains so when it again returns to its normal condition. If, finally, it is heated until it reaches its critical temperature, 580° C. (1076° F.), it becomes again non-magnetic and remains so until cooled to —20° C.

The success of the nickel-steel armor plate at the recent tests at Annapolis, have had, and will probably continue to have, a most important influence upon the manufacture of nickel steel, but whether the results then obtained justify the popular great expectations of this alloy remains to be seen.



The Creusot Steel, Nickel Steel, and the Cammell Compound Armor Plates.

Nickel Steel, and the Cammell Compound Armor Plates.

(*Garrison.*)

A similar series of tests were made at Ochta, near St. Petersburg, Russia, November 11, 1890. Three 8 x 8 feet x 10-inch plates were tested; they were made by the well-known firms of Brown, Vickers (both English) and Schneider, of Creusot, France.* It was not known for certain whether the latter plate contained any nickel—probably it did not. Such being the case, these tests have no especial interest in this connection.

In *Fig. 7* we have a reproduction from a photograph of the plates tested at Annapolis, taken after the completion of the tests. There were three plates in all; an ordinary Creusot steel plate shown on the left, a Creusot nickel-steel plate in the centre, and a compound Cammell† plate on the right.

Four six-inch chrome steel projectiles (Holtzer) were fired at each, then the tests were completed by firing one eight-inch Firth shell at the centre of each plate.

All the projectiles perforated the compound plate and lodged in the backing. None of them perforated the steel plate; they either remained lodged in it, or else rebounded entire or in fragments. The plate, however, was cracked entirely through from top to bottom. Three of the projectiles lodged entire in the nickel-steel plate, the other two broke in fragments, their points remaining in the plate. The plate, however, remained entirely uncracked, although it showed slightly less resistance than the ordinary steel plate.‡

Silicon Steel.—For a number of years past it has been a common belief that steel, or more particularly forged steel, should contain as small amount of silicon as possible. Any amount exceeding ·10 per cent., or at most ·20 per cent., was considered highly injurious to its strength and ductility. From recent investigations it now seems, provided the amount carbon present be very small, the considerable amounts of silicon present in such steel (constituting

* *Engineer*, Nov. 21, 1890, p. 409.

† Made by Cammell & Co., Sheffield, England.

‡ *Report of Board*, Oct. 11, 1890.

the so-called "silicon steel") produce excellent results as to toughness and malleability.

The *rôle* which silicon plays in cast iron and in steel is a most interesting one, and, until quite recently, its action was not properly understood. According to the investigations of Keep* and Turner, white carbonaceous cast iron, which would invariably give porous and brittle castings, is made free from honeycombs, and possesses much greater strength by the addition of comparatively small amounts of silicon.

The exact condition with which silicon is combined with iron is still a matter of dispute. In general, its effect upon iron is to change the carbon from the combined to the graphitic state. The amount of silicon required to produce a strong cast iron depends greatly upon the condition in which the carbon exists in the iron to begin with. The amount and relative conditions of the carbon present is also, to a greater or less degree, regulated by the amount of silicon present. It is safe to consider, as a general rule, that an increase of silicon changes the combined carbon to graphitic, and *vice versa*.

After the introduction of the Bessemer process it was observed that a certain definite percentage of silicon in the pig iron employed was necessary in order to produce good steel. This proportion was upwards of 1·5 per cent. Gautier† states when silicon is introduced in certain definite proportions into liquid steel, it enables blowholes to be eliminated. The effect of the presence of silicon in the Bessemer process is that of allowing the temperature of the metal to be kept higher than is otherwise attainable. The intense heat developed by the burning of the silicon in the Bessemer converter causes the silica produced by its oxidation to remain in the bath and to retain all its heat, in which respect it differs entirely from carbonic oxide, which is the product of the oxidation of the carbon.

Turner states that the density of cast iron is decreased

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* *Journal of the Iron and Steel Institute*, No. 2, 1889, p. 226. British Association, 1888. *Trans. Am. Inst. of Mining Engineers*, vol. xvii.

† *Journal of the Iron and Steel Institute*, No. 2, 1886, p. 743 and 744.

with tolerable uniformity by the addition of silicon. Osmond, in his experiments to determine the "critical points of iron and steel," states that silicon is alloyed with the iron, but does not form with it any definite compounds.*

Silicon steel is made from a rich, siliceous pig iron, known as "ferro-silicon," in much the same way as manganese steel is produced from ferro-manganese. Ferro-silicon is practically a pig iron containing from seven to fourteen per cent. silicon, and of a very high grade in other respects. Silicon has a remarkable affinity for iron; recent investigations have shown that iron will combine with seven or eight times more silicon than carbon. This amount may be somewhat further increased with the presence of an unusual amount of manganese. Keep† found that the loss of silicon in remelting silicon irons was trifling. He also found that in alloying silicon irons with scrap or pig iron, deficient in silicon, the silicon is practically all retained in the mixture.‡

The amount of silicon present in silicon steel, with which the best results have been obtained, is about two per cent., and with about 0·19 per cent. of carbon.

It will be observed from the table that one and one-half to one and three-fourths per cent. silicon increases the limit of elasticity and raises the tensile strength, but does not impair ductility. A further increase in tensile strength, however, can only be obtained by this means at the expense of ductility. A slight increase above two per cent. of silicon possesses marked changes in the characteristics of the material. In this respect its action resembles that of carbon in contradistinction to the action of manganese. It will be observed that with 1·5 to two per cent. silicon present the material possesses twenty-five to thirty per cent. elongation; whereas, the same percentage of carbon in the iron would give a product barely malleable and with practically no elongation under tensile stress.

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* *Journal of the Iron and Steel Institute*, No. 1, 1890, p. 63.

† *Trans. Am. Inst. of Mining Engineers*, vol. xvii, p. 258.

‡ *Ibid.* p. 261.

Unlike manganese steel, no further addition of silicon will effect a return of strength. When the amount of silicon exceeds six per cent. the steel is red-short, will not forge but crumbles at a low heat, notwithstanding the small amount (0·25 per cent.) of carbon present.

It is, therefore, obvious that as the amount of carbon present increases, the point of malleability ceases with a much lower percentage of silicon.

Unlike carbon, silicon does not confer the property of hardening upon iron when dipped hot into a cooling medium. It resembles manganese somewhat in this respect.

According to Gautier* some splendid tools have been made at the Hecla Works, Sheffield, with steel containing 1·5 per cent. silicon and less than 0·5 per cent. carbon.

Gautier reports the following silicon steels as producing excellent results.†

	C.	*Si.*	*Mn.*	*P.*
1,	0·783	0·342	0·370	0·019±
2,	0·826	0·840	0·430	0·019±
3,	0·574	0·478	0·200	0·019±
4,	1·075	0·675	0·520	0·023±
5,	1·091	0·690	0·370	0·019
6,	1·114	0·684	0·40	—
7,	0·941	0·877	0·36	0·028
8,	1·050	0·299	0·41	0·015
9,	1·188	0·575	0·40	0·018

One of the effects of the silicon on steel is probably similar to that of manganese. The silicon reduces part of the oxide of iron present in the steel forming silica which combines with the remainder of the oxide of iron forming a silicate, which rises to the top and is fluxed off more or less completely according to its condition of aggregation.‡

It must not be supposed that silicon can take the place of carbon, the latter must always have the advantage of being more easily applied and of producing a material

* *Journal of the Iron and Steel Institute*, No. 11, 1889, p. 244.

† "Les Alliages Métalliques," excerpt *Bulletin Soc. Minerale*, 2d Ser., III, 1889, pp. 91–92.

‡ Howe's *Metallurgy of Steel*, vol. I, p. 41.

ALLOYS OF IRON AND SILICON.

ANALYSIS PER CENT.					Drillings taken from.	How Ingot Forged.	Whether Tested in Annealed or Unannealed Condition.	Original Diameter (Inches).	Limit of Elasticity in Tons per Square Inch.	Amount of Stretch in Inches at Elastic Limit.	Breaking Load in Tons per Square Inch on Original Area.	Total Extension Per Cent.	Reduction of Area Per Cent.	Appearance of Fracture of Test Bar.	Appearance of Fracture of Annealed Forged Bar from which Test Bar was prepared.
Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.											
'14	'24	'08	'03	'14	Ingot.	Fairy well.	—	—	—	—	—	—	—	—	—
—	'18	—	—	—	Test bar.	—	Unannealed.	'7979	22·00	'0065	33·00	30·05	54·54	Silky.	—
—	'20	—	—	—	Test bar.	—	Annealed.	'7979	15·17	'0095	25·00	37·55	60·74	Silky.	Mild and rather burnt.
—	—	—	—	—	—	—	Annealed.	'898	15·17	—	23·44	16·9	42·7	Silky, but with a large reedy flaw.	—
'18	'79	—	—	'21	Ingot.	Very well.	—	—	—	—	—	—	—	—	—
—	'70	—	—	—	Test bar.	—	Unannealed.	'7979	25·00	'013	34·00	29·50	54·54	Silky.	—
—	'73	—	—	—	Test bar.	—	Annealed.	'7979	19·00	'0045	29·50	34·02	52·66	Silky.	Mild, close, granular.
—	'87	—	—	—	—	—	Annealed.	'7979	19·00	—	28·50	25.45	42·56	Silky.	—
—	—	—	—	—	—	—	—	'898	18·16	—	27·49	26·5	66·4	Silky at edges, very finely granular at centre.	—
'19	1·60	—	—	'28	Ingot.	Very well.	—	—	—	—	—	—	—	—	—
—	1·60	—	—	—	Test bar.	—	Unannealed.	'7979	28·0	'008	37·5	31·10	50·58	Centre silky, outside finally crystalline.	—
—	1·52	—	—	—	Test bar.	—	Annealed.	'7979	25·0	'0045	33·00	35·10	54·52	Silky.	Mild, close, granular.
—	—	—	—	—	—	—	—	'898	23·09	—	32·5	24·3	58·3	Silky at edges, very finely granular at centre.	—
'20	2·18	'06	'04	'25	Ingot.	Very well.	—	—	—	—	—	—	—	—	—
—	2·11	—	—	—	Test bar.	—	Unannealed.	.7979	31·00	'004	39·5	18·48	28·02	Silky.	—
—	2·13	—	—	—	Test bar.	—	Annealed.	'7979	25·50	'006	34·0	36·30	59·96	Silky.	Granular, but crystals much larger.
—	—	—	—	—	—	—	—	'898	20·22	—	27·98	5·6	—	Broke in screw thread ('93" diameter), fracture somewhat coarsely crystalline.	—
'20	2·67	—	—	'25	Ingot.	Very well.	—	—	—	—	—	—	—	—	—
—	2·69	—	—	—	Test bar.	—	Unannealed.	'7979	32·0	'0065	42·5	17·6	24·36	Coarse and slightly granular.	—
—	2·67	—	—	—	Test bar.	—	Annealed.	'7979	24·0	'0052	32·0	6·05	6·64	Coarse and granular.	Coarse, open.
—	—	—	—	—	—	—	—	'898	23·5	—	28·52	2·5	—	Broke in screw thread ('93" diameter), fracture somewhat coarsely crystalline.	—
'21	3·46	—	—	'29	Ingot.	Very well.	—	—	—	—	—	—	—	—	—
—	3·39	—	—	—	Test bar.	—	Unannealed.	'7979	35·0	'01	47·5	11·10	14·22	Coarse and slightly granular.	—
—	3·36	—	—	—	Test bar.	—	Annealed.	'7979	30·0	'009	39·0	8·83	9·28	Coarse and granular.	Coarse, open.
—	—	—	—	—	—	—	—	'803	29·45	—	34·17	3·2	5·65	Entirely and somewhat coarsely crystalline.	—
'25	4·49	—	—	'36	Ingot.	Very well.	—	—	—	—	—	—	—	—	—
—	4·18	—	—	—	Test bar.	—	Unannealed.	'7979	45·0	'003	49·0	'004	'20	Coarse and slightly granular.	—
—	4·23	—	—	—	Test bar.	—	Annealed.	'7979	None visible.	—	38·0	'64	'98	Coarse and granular.	Coarse, open.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
'26	5·53	'06	'04	'29	Ingot.	Very well.	—	—	—	—	—	—	—	—	—
—	4·9	—	—	—	Test bar.	—	Unannealed.	'7979	None visible.	—	48·0	'30	'70	Coarse and slightly granular.	—
—	4·80	—	—	—	Test bar.	—	Annealed.	'7979	25·0	'0075	25·0	'37	Broke in thread.	Broke in thread, coarse and granular.	Very coarse.
—	—	—	—	—	—	—	—	'803	None visible.	—	38·98	'7	1·98	Entirely and somewhat coarsely crystalline.	—
'04	7·23	—	—	'29	Ingot.	—	—	No test bar made, would not forge.				—	—	—	—
'08	8·83	'07	'05	'68	Ingot.	—	—	No test bar made, would not forge.				—	—	—	—

Per Cent.	Reduction of Area Per Cent.	Appearance of Fracture of Test Bar.	Appearance of Fracture of Annealed Forged Bar from which Test Bar was prepared.	Modulus of Elasticity by Professor Kennedy, in lbs. per Square Inch.	BENDING TEST OF ANN	
					Test by Hadfield.	
	—	—	—	—	—	
5	54·54	Silky.	—	—	—	
5	60·74	Silky.	Mild and rather burnt.	—	Bent double cold.	
	42·7	Silky, but with a large reedy flaw.	—	30,160,000	—	
	—	—	—	—	—	
0	54·54	Silky.	—	—	—	
2	52·66	Silky.	Mild, close, granular.	—	Bent double cold.	
5	42·56	Silky.	—	—	—	
	66·4	Silky at edges, very finely granular at centre.	—	29,970,000	—	
	—	—	—	—	—	
0	50·58	Centre silky, outside finally crystalline.	—	—	—	
0	54·32	Silky.	Mild, close, granular.	—	Bent double cold.	
	58·3	Silky at edges, very finely granular at centre.	—	29,600,000	—	
	—	—	—	—	—	
8	28·02	Silky.	—	—	—	
0	59·96	Silky.	Granular, but crystals much larger.	—	Bent double cold.	
	—	Broke in screw thread ('93" diameter), fracture somewhat coarsely crystalline.	—	26,200,000	—	
	—	—	—	—	—	
	24·36	Coarse and slightly granular.	—	—	—	
5	6·64	Coarse and granular.	Coarse, open.	—	Bent double, but broke i radius with last blow	
	—	Broke in screw thread ('93" diameter), fracture somewhat coarsely crystalline.	—	28,500,000	—	
	—	—	—	—	—	
0	14·22	Coarse and slightly granular.	—	—	—	
5	9·28	Coarse and granular.	Coarse, open.	—	Bent only to right angle much stiffer.	
	5·65	Entirely and somewhat coarsely crystalline.	—	28,410,000	—	
	—	—	—	—	—	
04	·20	Coarse and slightly granular.	—	—	—	
4	·98	Coarse and granular.	Coarse, open.	—	Very brittle, would no bend at all.	
	—	—	—	—	—	
	—	—	—	—	—	
0	·70	Coarse and slightly granular.	—	—	—	
7	Broke in thread.	Broke in thread, coarse and granular.	Very coarse.	—	Very brittle, would no bend at all.	
	1·98	Entirely and somewhat coarsely crystalline.	—	28,650,000	—	
	—	—	—	—	—	
	—	—	—	—	—	

g Test of Annealed Bars, ½" wide by ¼" thick.		
by Hadfield.	Test by Turner.	Relative Hardness Determined by Professor Turner in Flat Bars, ½" × ¼".
—	—	—
—	—	—
uble cold.	Bent cold through 180°, radius ⅜", perfect.	20
—	—	—
—	—	—
—	—	—
uble cold.	Bent cold through 180°, radius ⅜", perfect.	20
—	—	—
—	—	—
—	—	—
—	—	—
uble cold.	Bent cold through 180°, radius ⅜", perfect.	24
—	—	—
—	—	—
—	—	—
uble cold.	Bent cold through 180°, radius ⅜", perfect.	24
—	—	—
—	—	—
—	—	—
uble, but broke in with last blow	Bent through 180°, but broke off sharp at bend.	26
—	—	—
—	—	—
—	—	—
ly to right angle, stiffer.	Broke at 45°.	30
—	—	—
—	—	—
—	—	—
ittle, would not at all.	Broke at 15°.	33
—	—	—
—	—	—
—	—	—
ittle, would not at all.	Snapped in three pieces at first blow of hammer.	36
—	—	—
—	—	—
—	—	—

more suited to the various requirements of all classes of engineers.

Some of the silicon steel alloys are at present of no practical use and have no other than scientific interest, but it is, of course, impossible to conjecture to what uses they might be put in the future or how their properties could be improved by various changes.

The electrical resistance of silicon steel is nearly as great as that of manganese steel or approximately from four to seven times that of iron.

Tungsten Steel.—Although the metal tungsten itself is infusible, it readily unites with iron, forming an alloy known as ferro-tungsten. In this form is used in the preparation of tungsten steel.

Formerly the oxide of tungsten was melted with Swedish or good hematite pig-iron drillings; the drillings or turnings being used to secure a better action between the carbon and the oxide of tungsten. The process is, therefore, similar to that of making ordinary steel, in which the manganese oxide and the tungstic oxide change places. Now, however, the steel is first melted, not carbonized, and ferro-tungsten of known composition added to the same. By this modification, its manufacture is much more under control and the products more uniform.

The general effect of tungsten on steel is to render it intensely hard and brittle. It is very difficult to forge, and it cannot be welded when the amount of tungsten present exceeds two per cent. It is, therefore, not only unfit for structural purposes, but also for tools subject to shock, such as rock drills, chisels, hammers, etc. Of course, the degrees of brittleness and hardness are dependent upon the amount of tungsten present in the steel. Some steels have been made very hard and also had their toughness increased with a small percentage of tungsten.

In 1844, the Duc de Luynes found that in nine analyses of oriental damasked steel, steel tungsten appeared in each. In six, but as a trace, whilst in the other two, one contained 0·518 per cent. and the other one per cent. of tungsten.*

* Percy, *Metallurgy of Iron and Steel*, p. 189.

According to Chernoff, tungsten steel after a few heatings becomes oxidized and loses its special properties.

The use of tungsten steel seems to be increasing in France notwithstanding its high price (by reason of the scarcity of tungsten). The St. Chamond Company use it for springs, claiming it to possess a carrying power about one-third greater than the best carbon spring steel.

One peculiarity of tungsten steel is that in the absence of carbon it is not strengthened or increased in hardness by tempering. When the amount of tungsten present becomes considerable these steels can be worked only with the greatest difficulty. The higher grades cannot be cut by the file, and as none of it can be tempered, it must be shaped at one forging, and then ground to the form desired.

Tungsten steel is obviously especially useful for standard gauges, tools, etc. The presence of tungsten greatly increases the magnetism of steel, although, unlike nickel, it is not magnetic itself.

TUNGSTEN STEEL. *Howe.*

	Source, etc.	Composition.						Tensile Strength. Pounds Per Square Inch.	Elongation. Per Cent.
		W.	Fe.	C.	Si.	Mn.	P.		
1.	Schneider,	11·03	—	2·15	·26	1·49	·007	—	—
2.	Mushet's special,	9·99	—	1·24	0·33	1·04	·04	—	—
3.	" "	7·81	—	1·99	·09	·19	—	146,400	0
4.	English,	8·25	—	1·70	0·82	1·26	—	—	—
5.	"Crescent Hardened," Pittsburgh,	6·73	—	2·06	·05	2·66	—	{ 76,100 *a* { 94,000 *b*	0
6.	"Imperial," Pittsburgh,	6·38	—	1·6	·16	2·11	—	—	—
7.	" "	—	—	—	—	—	—	{ 67,000 { 91,000	0
8.	Ledebur,	8·81	—	·42	·76	2·57	—	—	—
9.	"	8·74	—	·38	·76	2·46	—	—	—
10.	Styrian,	6·45	—	1·90	·21	·35	—	190,000	0·75
11.	Bochum,	3·05	95·85	—	—	tr.	—	—	—
12.	"	2·71	96·37	—	—	tr.	—	—	—
13.	"	1·94	—	1·43	·19	·44	—	—	—
14.	De Fenffe,	—	—	—	—	—	—	153,300	—
15.	"	—	—	—	—	—	—	166,500	—

1. L. Schneider, *Oest. Zeit.*, 1885, XXXIII, p. 257; *Journ. Iron and St. Inst.*, 1884, I, p. 230. 2. Hard English Mushet's Steel, *Metallurgical Rev.*, II, p. 441. 3. The same tested by Howe. 4. Ledebur, *Handbuch*, p. 263. 5. Made by Miller, Metcalf & Parkin, tested by Howe. 6 and 7. Made by Park Bros. & Co., and tested by Howe. 8, 9 and 10. Ledebur, *loc. cit.* 11 and 12. Percy, *Iron and Steel*, p. 194. 13. Ledebur, *loc. cit.* 14 and 15. *Rev. Univ.*, 1860, p. 88. *a.* As received from the makers. *b.* Quenched in oil from very dull redness.

Like chrome steel, tungsten tool steel can be worked easily at red heat, but to obtain the best results it must be handled with the greatest care.

TUNGSTEN STEEL. *Holtzer.*

Number.	Tensile Strength. Pounds per Sq. In.			Elastic Limit. Pounds per Square Inch.			Elongation. Per Cent. in 7·9″.			Contr ction of Area. Per Cent.		
	Natural State.	Oil-hardened and Temp'd.	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Temp'd.	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Temp'd.	Oil-hardened and Annealed.	Natural State.	Oil hardened and Temp'd.	Oil-hardened and Annealed.
1	68,553	—	—	47,504	—	—	23·7	—	—	75·5	—	—
	—	82,492	—	—	67,558	—	—	17·5	—	—	66	—
	—	—	76,092	—	—	52,197	—	—	19·5	—	—	72·3
2	71,114	—	—	50,348	—	—	23·5	—	—	60	—	—
	—	71,114	—	—	48,499	—	—	8·2	—	—	6	—
	—	—	93,017	—	—	—	—	—	15	—	—	59
3	77,941	—	—	41,672	—	—	23·5	—	—	45·1	—	—
	—	179,349	—	—	135,117	—	—	2·5	—	—	2·5	—
	—	—	116,769	—	—	90,172	—	—	10·2	—	—	40
4	93,017	—	—	47,504	—	—	17	—	—	33	—	—
	—	216,186	—	—	—	—	—	4·5	—	—	4	—
	—	—	134,406	—	—	104,538	—	—	8·5	—	—	24
5	106,386	—	—	62,580	—	—	9	—	—	—	—	—
	—	213,342	—	—	—	—	—	2·8	—	—	1	—
	—	—	140,806	—	—	109,230	—	—	8·3	—	—	27

The "natural state" pieces are simply cooled slowly after forging.
The "oil-hardened and tempered" pieces are quenched in oil from a low yellow heat and slightly reheated.
The "oil-hardened and annealed" pieces are simply quenched, reheated to very dull redness, and cooled slowly.